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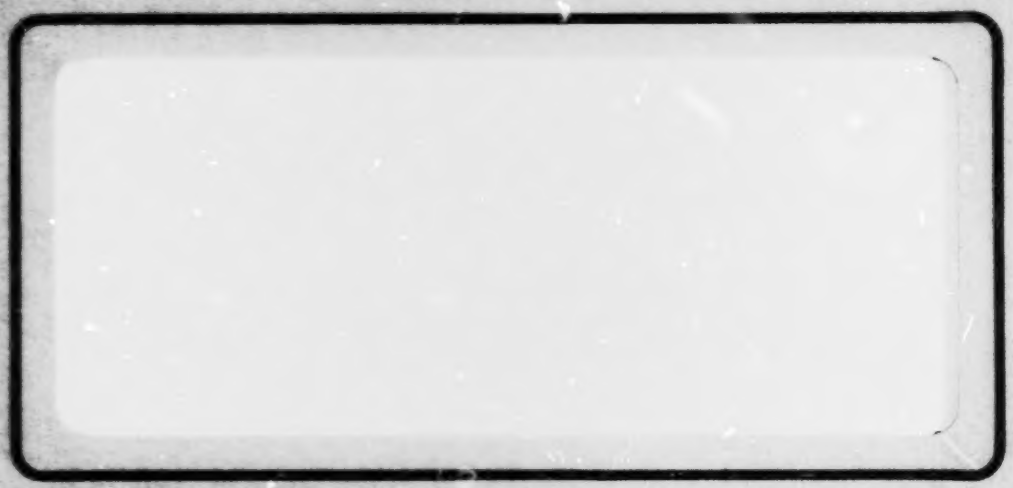

Alberta
AGRICULTURE

DISEASES OF TREES AND ORNAMENTALS IN ALBERTA

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This is a revision of A.H.R.C. Pamphlet 81-12 of the same title. All outdated copies should be discarded.

FOREWORD

This handbook is designed to assist nurserymen, landscapers, parksmen and other professional horticulturists in the diagnosis and treatment of diseased trees and ornamentals. It may also serve as a source of information for garden store operators who must answer customer's questions about plant diseases and their control. This publication is not intended to be a comprehensive treatment of plant disease problems on all trees and ornamentals; rather, it includes information on the major diseases likely to be encountered. In difficult or questionable situations, the opinion of a professional plant pathologist should be sought. Control recommendations, particularly those involving chemical pesticides, are subject to periodic change. Reference to products in this publication is for the reader's convenience. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Additional copies of this publication can be obtained from: Library, Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta T0J 0J0.

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I. GENERAL INFORMATION

Air Pollution Injury

The extent and severity of air pollution injury to ornamental plants and trees in Alberta has not been systematically studied. However, there are many individual cases on record where air pollutants have caused substantial injury to native and cultivated plants. As industrial and refining activities in Alberta expand and existing population centers increase in size, so will the incidence and severity of air pollution injury.

Injury caused by air pollution is often evident on plants before it has a noticeable effect on humans or animals. Pollution injury is likely to be more common near large cities, smelters, refineries, electric power plants, airports, highways and streets where motor vehicle traffic is heavy, incinerators and refuse dumps, pulp and paper mills, and coal, gas and petroleum-burning furnaces. Plant injury may also occur near industries that produce brick, pottery, cement, aluminium, copper, nickel, iron, steel, zinc, acids, ceramics, glass, phosphate fertilizers, paints, stains, rubber, soaps, detergents and other chemicals.

The effects of pollution on plants include: mottled foliage, "burning" at the tips or edges of the leaves, dieback of twigs, growth suppression, early leaf drop, delayed maturity, abortion or early drop of blossoms, and reduced yields and lower quality of produce in the case of some agricultural crops.

The factors governing the extent of the damage and the regions in which air pollution is a problem are: 1) concentration and type of pollutant, 2) distance from the source, 3) length of exposure, and 4) prevailing weather conditions. Other important factors are city size and location, land topography and air drainage, soil moisture and nutrient supply, maturity of plant tissues, time of year, species and varieties (cultivars) of plants grown, and other various conditions. Extremes of temperature, humidity and light or a soil moisture deficit can alter a plant's response to an air pollutant.

The damage caused by air pollution is usually most severe during warm, clear, still or humid weather when barometric pressure is high. Toxicants accumulate near the earth's surface when warm air aloft traps cooler air at the ground level, a phenomenon called "air inversion".

Injury from air pollution can be confused with many things, e.g., the disease symptoms caused by fungi, bacteria, viruses, mycoplasmas and nematodes; insect and mite damage; genetic disorders; nutritional deficiencies and toxicities; natural senescence; abuse of plants by man; and the adverse effects of temperature, wind and water. In general, the visible injury to plants is of three types: 1) collapse of leaf tissue with the development of dead areas, 2) yellowing or other color changes, and 3) alterations in growth.

The air contaminants responsible for damage may be either gaseous or particulate in nature. The solid particles released into the atmosphere are sometimes the cause of soiled fruits and vegetables, fruit and growth reduction and damage to the tissue of exposed leaves and fruit, as well as adding a toxic burden to forage crops used as feedstuffs for livestock. Liquid particles such as acid aerosols and toxic mists are sometimes responsible for leaf spotting. The greatest amount of damage to animals and vegetation is usually caused by gaseous air contaminants which directly injure plants and indirectly injure animals by the toxic effects produced after the animal has consumed contaminated forage and food supplements.

Particulates

A number of particulate materials, such as carbon and cement dusts, occur in the atmosphere and form undesirable deposits on agricultural produce. Injury to leaves and fruits of many plants may result from acid aerosols originating from the combustion of sulphur-containing fuels, smelting of ores and chemical manufacture. Sulfuric and other acid aerosols produce spots of variable sizes on the upper exposed surface of leaves. Injury usually occurs during periods of fog when the droplets become large enough to settle out and leaves readily wet. However, acid aerosol damage also occurs any time the gas affluent dew point permits droplet formation.

There appears to be little doubt that naturally deposited dust from certain cement plants is responsible for injury to leaves of deciduous and coniferous species and occasionally for death of the latter. Injury results from the combination of a relatively thick crust deposit and the toxicity of alkaline solutions formed when dusts are deposited in the presence of free moisture. Also, the finer particles of certain cement-kiln dusts from electrostatic precipitators interfere with carbon dioxide exchange and may cause considerable leaf injury.

Gases

The principal gaseous air pollutants that cause damage to vegetation in North America are sulphur dioxide, fluorides, chlorine, ozone, PAN and ethylene. Injury due to gaseous pollutants can be identified by the appearance of characteristic symptoms. Knowing the relative sensitivity of various plants may be of assistance in identifying specific pollutants. Following are some descriptions of the injury symptoms on plants caused by the major air pollutants.

1. SULPHUR DIOXIDE (SO_2). The exposure of succulent, broadleaved plants to SO_2 (and its by-product, sulphuric acid) usually results in dry, papery blotches that are generally white to straw colored and marginal or interveinal. On some species, chronic injury results in brown to reddish-brown or black blotches. Both the upper and lower leaf surfaces are affected. The leaf veins normally remain green. Chlorosis (yellowing) and a gradual bleaching of the surrounding tissues is fairly common. Injured grass blades develop light tan to white streaks on either side of the midvein. A tan to reddish-brown dieback or banding occurs on conifer leaves, with adjacent chlorotic areas. Growth

suppression, reduction in yield and heavy defoliation may also occur. Middle-aged leaves and young plants are most susceptible to SO_2.

Sulphur dioxide injury can be severe 50 km or more from its source - usually electric power plants, copper and iron smelters, oil refineries, chemical factories and other industries that burn soft coal, coke or high-sulphur oil as fuel.

Concentration. - The degree of injury increases as both the concentration of sulphur dioxide and/or the length of exposure increases. Sensitive plants are injured by exposures of 0.5 ppm (parts per million) for four hours or 0.25 ppm for 8-24 hours. Plants are most sensitive to SO_2 during periods of bright sun, high relative humidity and adequate plant moisture during the late spring and early summer.

Very sensitive plants. - Alfalfa, amaranthus, apple, apricot, ash (green and white), aspen, aster, bachelor's button, barley, bean (broad and garden), beech, beet (table and sugar), begonia, bindweed, birch, blackberry, bluegrass (annual), broccoli, bromegrass, Brussel's sprouts, buckwheat, carrot, chickweed, China aster, clovers, columbine, cosmos, cotton, crabapple, dahlia, dandelion, Douglas fir, eggplant, elm, endive, fir (white), fleabane, hawthorn (scarlet), larch, lettuce (garden and prickly), mallow, morninglory, mustard, oats, orchardgrass, peach, pear, pepper (bell and chili), petunia, pine (Austrian, jack, ponderosa, white), plantain, polygonum, poplar, pumpkin, quince, radish, ragweed, raspberry, rhubarb, rose, rye, ryegrass, safflower, smartweed, soybean, spinach, spruce, squash, strawberry, sumac, sunflower, sweet pea, sweet potato, Swiss chard, tomato, tulip tree, turnip, velvetweed, verbena, violet, wheat and zinnia.

Somewhat resistant plants. - Arborvitae, boxelder, canna, castor bean, celery, chrysanthemum, corn, cucumber, gingko, gladiolus, gourds, hibiscus, honeysuckle, horseradish, iris, johnsongrass, lilac, maple, milkweed, mock orange, muskmelon, most oaks, onion, potato, purslane, shepherd's purse, snowball, sorghum, tulip, viburnum, Virginia creeper and willow.

2. FLUORIDES (F). - The typical injury by gaseous or particulate fluorides is a yellowish mottle to a wavy, reddish-brown or tan "scorching" at th margins and tips of broadleaved plants, and a "tip burn" of grasses and conifers. A narrow, chlorotic to dark brown band often occurs between living and dead tissue. Poplar, sweet cherry and corn foliage exhibit a chlorotic mottling, streaking or blotching prior to the development of the typical "burned" area. Leaves and fruits, such as apple, apricot, peach and plum, may fall prematurely. Injured areas in stone fruit leaves may become brittle and drop out leaving shot-holes. The young succulent growth is injured the easiest. Fruits may soften or become necrotic at the blossom end. Fluoride-contaminated forage that is eaten by cattle or sheep may cause fluorosis. Fluorides (compounds containing the element fluorine) are produced to a high degree by glass, aluminium, pottery, brick and ceramic industries and by refineries, metal smelters and phosphate fertilizer factories.

Concentration. - Accumulated leaf-fluoride concentrations of 20-150 ppm often result in injury to sensi[illegible] plants, although resistant varieties and species of plants will tol[illegible]e leaf concentrations of 400 - 4,000 ppm or more without visible injury. The extent of tissue damage is related to the dosage and the quantity of fluoride accumulated.

Very sensitive plants. - Alfalfa, apple, apricot, barley, blueberry, box elder, buckwheat, canna, cat-tail, cherry, chickweed, corn (sweet), crabgrass, cyclamen, Douglas fir, gladiolus, iris, Jerusalem cherry, Johnsongrass, larch (western), mahonia, maple, goosefoot, some oaks, oxalis, peach, peony, most pines, plum, poplar, smartweed, sorghum, spruce (blue and white), and tulip.

Somewhat resistant plants. - Asparagus, bean, birch (cutleaf), burdock, cauliflower, celery, cherry (flowering), chrysanthemum, citrus, columbine, cucumber, currant, dandelion, dock, dogwood, egg plant, elderberry, elm (American), most junipers, lettuce (Romaine), linden (American), lobelia, locust, marigold, mountain ash (European), nightshade, onion, orchardgrass, parsnip, pear, pepper, petunia, pigweed, plum (flowering), plantain, purslane, pyracantha, ragweed, rhododendron, rose, snapdragon, soybean, spinach, squash, spruce (Englemann), strawberry, sweet pea, tobacco, tomato, Virgina creeper, willow (weeping), wheat and zinnia.

3. CHLORINE (Cl_2). Chlorine injury is somewhat similar to that caused by sulphur dioxide and fluorides in that it is marginal and interveinal. Two types of damage generally occur: 1) with broadleaved plants, necrotic, bleached or tan to brown areas that tend to be near the leaf margins, tips and between the principal veins, and 2) with grasses, progressive streaking toward the main vein in the region between the tip and the point where the grass blade bends, usually occurring alongside the veins. Middle-aged leaves or older ones are usually more susceptible than young ones. Bleaching without killing can occur, as well as tissue collapse. Conifers may show tip burn on the current season's needles.

Hydrogen chloride and chlorine are emitted from the stacks of glass-making factories and refineries. These gases are also produced by incineration, scrap burning, and as the result of spillage, such as from chlorine storage tanks. Chlorine-injured vegetation is often observed near swimming pools, water purification plants and sewage disposal facilities.

Concentration. - Very susceptible plants show symptoms when exposed for two hours or more at concentrations of chlorine ranging from 0.1 to 4.67 ppm. Chlorides do not accumulate in plant tissues after exposure to chlorine.

Very sensitive plants. - Alfalfa, amaranthus, apple, ash, barberry, basswood, bean (Pinto), blackberry, bluegrass (annual), box elder, buckwheat, cherry, chickweed, chokecherry, coleus, cosmos, cucumber, dandelion, dogwood, gomphrena, grape, honeysuckle, horse chestnut, hydrangea, Johnsongrass, juniper, lilac, mallow, maple (Norway, silver, sugar), may apple, morning glory, mustard, onion, peach, peony, petunia,

phlox, pine (jack, loblolly, white), poison ivy, primrose, radish, rose (tea), spruce (Norway), sunflower, tomato, tulip, violet, Virgina creeper and zinnia.

Somewhat resistant plants. - Arborvitae, begonia, ivy (Boston), daylily, eggplant, iris, lamb's-quarters, maple (Japanese), oak (red), oxalis, pepper, pigweed, polygonum, Russian olive and soybean.

4. OZONE (O_3). Ozone is a very active form of oxygen that causes a variety of symptoms, including tissue collapse, interveinal necrosis and markings on the upper surface of leaves known as stipple (pigmented yellow, light tan, red-brown, dark brown, red, black or purple), flecking (silver or bleached straw white), mottling, chlorosis, bronzing, bleaching, and a margin rolling and scorching of leaves on lilac. Growth of affected plants is usually stunted, and flowering and bud formation are depressed. The affected leaves of certain plants, such as citrus, grape and pines, commonly wither and drop early. Conifers frequently show a yellow to brown mottling and tip burn or a yellow to brown or orange-red flecking and banding of the needles. Susceptible white pines are stunted and chlorotic. The injury pattern in small grains and forage grasses generally occurs as a scattering of small, yellowish or white to tan flecks on one or both leaf surfaces. The flecks may later merge to form larger, bleached white to yellowish dead areas. Ozone usually attacks nearly mature leaves first, progressing to younger and older leaves. Young plants are generally the most sensitive to ozone; mature plants are relatively resistant. Ozone-killed tissues are readily infected by certain fungi, e.g., Botrytis.

Ozone is brought down from the upper atmosphere by vertical winds produced during electrical storms. However, more importantly, it is produced when sunlight reacts with nitrogen oxides and hydrocarbons formed by refuse burning and combustion of coal or petroleum fuels, especially from internal combustion engines. When oxidant levels in the air are high, more than 90% is ozone. These levels are usually at their highest around noon and relatively low at night.

Concentration. - The exposure of sensitive plants for 4-6 hours at levels of 0.02 to 0.04 ppm of air or more will produce injury patterns. Susceptible tobacco cultivars are injured (a condition called "weather fleck") when concentrations of ozone reach or exceed 0.04 parts per million. The extent of the injury depends on the plant species and environmental conditions prior to and during exposure. Ozone and SO_2 often combine to cause plant injury before either of these pollutants alone would cause damage.

Very sensitive plants. - Alfalfa, apricot, ash (green and white), aspen, aster, barley, bean (green and Pinto), beet (table and sugar), begonia, bentgrass, birch, bluegrass (annual), boxelder, broccoli, bromegrass, Brussels sprouts, carnation, carrot, celery, chicory, chickweed, Chinese cabbage, chrysanthemum, citrus, clover (red), corn (sweet), crabapple, crabgrass, dahlia, dill, duckweed, eggplant, endive, fuchsia, gourds, grape, larch (European), lilac, linden, locust (black), maple (silver and sugar), marigold, mint, muskmelon, oak (white), oat, onion, orchardgrass, parsley, parsnip, pea, peach, petunia, pine (ponderosa,

Scotch and white), potato, pumpkin, radish, rye, salvia, smartweed, snowberry, spinach, squash, strawberry, sweet potato, Swiss chard, tobacco, tomato, turnip, verbena, walnut, wheat and willow (weeping).

Somewhat resistant plants. - Coleus, cucumber, dogwood, geranium, gladiolus, impatiens, juniper (Pfizer), kalanchoe, most maples, most oaks, pepper and poinsettia.

5. PEROXYACETYL NITRATE (PAN). PAN is formed by oxides of nitrogen reacting with unsaturated hydrocarbons (simple olefins) in the presence of light. Like ozone, PAN is produced when sunlight reacts with various exhaust gases. PAN causes a collapse of tissue on the lower leaf surface of numerous plant species. The typical leaf marking is a glazing, bronzing or silvering that commonly develops in bands or blotches. On some plants, such as petunia, Pinto bean, tomato and tobacco, the collapse may be through the entire thickness of the leaf blade. In grasses, the collapsed tissue has a bleached appearance with tan to yellow, transverse bands. Conifer needles turn yellow. Early maturity or senescence, clorosis, moderate to severe stunting and premature leaf drop may also occur. PAN is most toxic to small plants and young leaves. The very young and most mature leaves are highly resistant.

Concentration. - Typical damage to susceptible plants occurs with PAN at levels of 0.01 to 0.05 ppm for an hour or more. Plant injury requires light before, during and after exposure. Injury is increased by any factor contributing to maximum plant growth. PAN is unstable, particularly at temperatures above 32°C.

Very sensitive plants. African violet, alfalfa, aster, bean (Pinto), beet (table and sugar), bluegrass (annual), carnation, celery, chickweed, dahlia, dandelion, dill, Douglas fir, endive, lettuce (Romaine), lilac, muskmelon, mustard, oat, certain orchids, pepper, petunia, pine (ponderosa), poinsettia, potato, primrose, rose, salvia, snapdragon, spinach, sunflower, Swiss chard, tobacco and tomato.

Somewhat resistant plants. Azalea, bean (lima), begonia, broccoli, cabbage, chrysanthemum, corn, cotton, cucumber, onion, pansy, periwinkle, radish, sorghum, touch-me-not and wheat.

6. ETHYLENE (H_2C-CH_2). Damage is often associated with PAN and ozone in urban areas, since ethylene is one of the many products of auto, truck and bus exhaust. Ethylene also results from the incomplete combustion of coal, gas and oil for heating and is a by-product of polyethylene manufacture. Ethylene modifies the activities of plant hormones and growth regulators affecting developing tissues and normal organ development without causing leaf tissue collapse and necrosis. Injury to broadleaved plants occurs as a downward curling of the leaves and shoots (epinasty), followed by a stunting of growth. Ethylene also causes dry sepal in Cattleya, Phalaenopsis and other orchids; "sleepiness" (an inward petal curling and failure of buds to open) in carnation, narcissus and rose; color breaking and blasted buds in roses; and the shelling (early drop) of azalea, snapdragon, stock larkspur and calceolaria blooms. More resistant, broadleaved plants and

grasses may only be stunted. Conifers drop their needles and young cones. New needle growth is stunted and cone development is poor. Similar symptoms are provided by other unsaturated hydrocarbons such as acetylene and propylene. Ethylene is a problem in fruit, vegetable and cut flower storage rooms and some greenhouses where open flame burners are used.

Concentration. - Air concentrations of 0.001 ppm for 24 hours will cause the sepals of orchid flowers to turn brown or wither and die. An exposure of 0.1 ppm for six hours will cause epinasty in tomato or pepper and "sleepiness" in carnation. The extent of injury depends on the air temperature, plant species and age of the organ as well as on the ethylene concentration.

Very sensitive plants. - Azalea, blackberry, buckwheat, calceolaria, carnation, cotton, cowpea, cucumber, larkspur, lilac, lily (Regal), marigold (African), narcissus, orchids, pea, peach, pepper, philodendron, potato, privet, roses, snapdragon, stock, sunflower, sweet pea, tomato and tulip.

Somewhat resistant plants. - Beet, cabbage, clover, endive, lettuce, oat, onion, radish, ryegrass and sorghum.

ANIMAL INJURY

Animals (not including insects, mites or nematodes) can injure plants in three general ways: 1) by wounding trunks, branches and roots; 2) by placing toxic chemical products on tissues and the soil; and 3) by causing soil compaction. Most wounds are caused by animals chewing, pecking, clawing or digging on or around plants. Low foliar and shoots can be chemically poisoned by urine. The soil environment around trees is usually altered by animal waste products or by the compressive effect of animal feet.

Animal Wounds on Trees

Chewing Injury. - Wounds from chewing are the most common type of animal injury on woody plants and are most frequently associated with rodents such as mice, rabbits, squirrels, porcupines and beaver. However, deer, cattle, horses, moose, elk and other grazing animals either seeking food from tender twigs and green bark or simply chewing bark out of curiosity or boredom, will also cause damage. Most chewing injury occurs in the winter when other sources of food are not available. Rodents are the most destructive group because they often feed on young seedlings in nurseries or on newly planted trees. Rodents often completely remove the bark of seedlings and young trees beneath the snow and can cause considerable losses in tree nurseries and plantations. Chewing injury can be controlled to some extent with animal repellants, such as thiram, applied in the fall. In areas where high populations of rodents are common, hardware cloth fencing should be placed from the soil surface to above the snow line around each tree. Population control with poison bait can also be used in some cases.

Pecking Injury. - Pecking wounds from birds can also be a problem on trees. The yellow-bellied sapsucker feeds on sap and insects attracted to sap. This bird pecks even rows of holes around the tree. These pecking wounds, when numerous, result in cankers that can kill patches of bark and, if sufficiently severe, can girdle the top of the tree. The yellow-bellied sapsucker has a wide tree host range and some of the preferred trees are thin-barked, e.g., apple, birch, Siberian elm, Colorado spruce, maple and Scots pine. To minimize sapsucker injury, install "scare" devices on trees, wrap trunks with protective materials and remove any potential nesting sites (large poplar with internal decay).

The grossbeak is another tree pest which feeds on terminals of young conifers and can be a severe problem in conifer nurseries and Christmas tree plantations. Sapsuckers and pine grossbeaks should not be confused with woodpeckers which are only seeking insect larvae in already dead and decayed wood in trees. For the most part woodpeckers are serving a beneficial function by alerting the homeowner of decay in trees and should not be disturbed.

Miscellaneous Animal Injury. - Confined farm animals and pets can also cause considerable injury to trees. Cattle and horses often remove trunk and root bark with their hooves, especially in rain-softened soil or in marshy areas. The root areas of trees adjacent to or inside

hooved-animal enclosures should be fenced off to protect them.

Cats often drag their claws over the bark of trees causing great bewilderment to homeowners as to the nature of the shredded bark. Dogs of all ages will often chew on bark of trees and shrubs when they are confined. They will also dig in soil around plants and cause injury to roots. Pet repellants can protect most high value trees and shrubs from pet injury.

Treatment of Animal Wounds. - Animal wounds should be treated like other mechanical injuries. Torn or looses bark should be removed and bark cut back until living tissues are found all around the wound. The wound should be shaped in a vertical ellipse. Bark around old wounds should be removed until callus is exposed. In extreme cases of girdling, twigs can be grafted across the wound ("bridge grafting").

Toxic Chemicals on Trees and Soil

Toxicity from urine is perhaps the most troublesome form of soil environment alternation by animals. Dogs are the most numerous and worst offenders around shade trees and shrubs. Male dogs use trees and shrubs for territorial markings and often the same plant is urinated upon by every passing male dog. Urine is a strong alkaline chemical that is damaging to foliage and branches. Injury is often most severe on evergreens. The most common symptoms are browning of the low branches in one location, usually near steps or at corners of buildings. The urine of female dogs often causes brown patches on lawns and could affect the roots of shrubs and small trees nearby. Although most injury is due to direct urine spray of foliage, there is some feeling that in high use urban areas a chemical modification of the soil may result from animal urine and feces. Trees sometimes die if included in animal enclosures, such as chicken yards, from the intensity of the manure. Fences and pet repellants can often prevent animal injury on preferred shrubs and trees.

Soil Compaction

Soil compaction by chained or penned animals can also harm trees and shrubs. Soil physically compressed in this manner is less permeable to moisture, nutrients and gases. Most soil compaction, however, is caused by humans (foot and vehicle traffic). Since animal and human soil compaction is the same, control recommendations are the same. Mulch should be put around trees and shrubs most likely to be affected before the soil compaction occurs. Already compacted soil must be loosened (an air hose attached to a root-feeding needle, or a crowbar, works quite well) and then mulch applied.

CLIMATIC INJURY

The major types of climatic injury occurring on trees and ornamentals in Alberta are temperature stress, moisture stress, physical damage from wind, snow and ice, and lightning injury.

1. TEMPERATURE STRESS

Extremes of temperatures, as well as rapid changes in temperature, can be injurious to trees and ornamental plants. In many cases there is interaction between temperature and moisture. The effects of temperature are most severe on newly planted plants which have not yet adjusted to their new environment. Native plants whose environments have changed around them, usually due to the activities of man, are also likely to be injured by extremes and rapid changes in temperature.

High Temperatures. - Whenever trees growing in deeply shaded locations are suddenly exposed to intense sunlight, stress occurs on the newly exposed bark from rapid temperature increases. This happens whenever a forested area is excessively thinned to create a house lot or recreation area and whenever trees are moved from a shaded nursery to an exposed location, such as the roadside or lawn. Two events may occur as a result of this type of stress: summer sunscald or winter sunscald. Summer sunscald is heat injury to the exposed bark during the summer and results in bark killing with subsequent canker formation. Wood beneath the dead bark is sometimes invaded by decay fungi and trees may break at this area a few years later. Winter sunscald is injury from rapid changes in bark temperature during cold and sunny winter days. Exposed bark, especially on species with dark bark, becomes much warmer on the sunny side than the air during these days but cools very rapidly after sunset. The rapid temperature changes can result in bark injury that usually occurs on the southwest side of the tree. Bark temperature reaches its maximum in midafternoon when the sun is in the southwest quadrant and, consequently, injury usually occurs most severely in that section of the tree. The other symptoms of winter sunscald injury are similar to those found in summer sunscald except that most trees, although often severely cankered on the southwest side, usually survive the injury.

Summer sunscald and winter sunscald can both be prevented in newly transplanted or recently exposed trees by wrapping trunks of trees with protective materials, such as Kraft paper, from the ground to the first branches. Summer sunscald may also require watering to relieve accompanying moisture stress. The light-colored wrap prevents excessive heating of the bark and should be left in place for at least two years. Most trees can adapt to increased exposure to the sun by producing a thicker bark, but it takes them about two years to accomplish these changes. The application of white water-base paint has also been found effective when applied to exposed portions of the trunk and branches; however, this method may be undesirable because the paint remains on the trees for several years.

Low Temperatures. - One of the major barriers to the geographic movement of plant materials by man is cold temperatures. Native plants that have been adapted to northern (temperate) climates are not usually injured by low temperatures. Exotic plants from more southern latitudes are not adapted to the freezing temperatures characteristic of northern locations and they are usually prone to cold temperature injury.

Woody plants have adapted to winter conditions by an established pattern of growth and dormancy that follows the yearly weather cycle very closely. They can tolerate extreme cold during the winter but little during the growing season. This phenomenon is termed "hardiness". As fall approaches woody plants begin to become progressively more cold hardy, and reach a peak of hardiness in mid-winter. Plants begin to decrease in hardiness during early spring and reach a low point of cold tolerance during the spring flush. This is the most vulnerable time for cold injury. A late spring frost can do considerable damage to many trees and can even kill whole trees. Injury is most commonly seen on flowering trees, such as crabapple and lilacs, whose flowers are often killed by late frosts. The later into the spring season the frost occurs the greater the chances that even native shrubs and trees will be injured.

Frost injury cannot be controlled but, in many cases, it can be prevented, especially where species have been planted north of their cold tolerance limits. Each species of tree and shrub is assigned a hardiness zone number that corresponds with the northernmost geographical area that the species can be planted safely. It is therefore very important to be aware of the cold tolerance of any tree or shrub before purchasing it or planting it. The Alberta Horticultural Guide contains information on hardiness of trees and herbaceous perennials.

Although hardiness normally increases in the fall, the plant can be "fooled" by late summer (after early July) fertilizer applications. High nitrogen fertilizers cause excessive foliage production and delay hardening. If these fertilizers are applied in late summer, they can cause flushes of foliage that may not have time to harden before fall frosts begin. Balanced fertilizers or those not excessively high in nitrogen should be applied to trees, shrubs and herbaceous perennials, and summer fertilization should be avoided.

Frost injury can be recognized by a browning or blackening of newly emerged shoots and flowers on the entire plant. However, in a frost pocket, only the lower parts of plants may be killed back. Injury to every plant of a particular species in a limited local area is also characteristic of frost injury. Check with local weather bureaus for low temperature data for the past two weeks if frost injury is suspected.

Rapid Changes in Temperatures. - Trees, in particular, can be injured by sudden and large increases or decreases in temperature, especially when the changes far exceed the normal range for the season of the year. A sudden increase in temperature or "Chinook" during the winter may cause premature flushing of foliage or a decrease in hardiness. The buds or

emerging foliage are often killed when the temperature again returns to its normal range. Sudden decreases in temperature can cause injury even when temperatures do not reach below freezing. Many "tender" species of trees and ornamentals are sensitive to sudden drops in temperature and may become injured when such drops occur. These plants should be grown in sheltered locations such as close to buildings or in courtyards to minimize large temperature changes.

2. MOISTURE STRESSES

a. Water Deficiency

Drought. - Perennial plants are subject to two kinds of water deficiency stress: 1) short-term drought during one growing season, and 2) long-term drought that accumulates moisture stress more than one growing season. The latter is the most important to perennials because, in contrast to annual crop plants, they are sensitive to year round moisture conditions.

An important contributing factor to moisture stress is subnormal rain and snowfall. There are, however, many site factors that increase the susceptibility of trees and ornamentals to moisture stress. Restricted root space is probably one of the most important contributing factors to moisture deficiency stress. In many cases, plants growing in confined locations, such as trees along a street, are sandwiched between roads, sidewalks, and driveways. These trees often are not able to extend their roots into sufficient soil for them to meet the demands for moisture of the crown. They can usually survive under normal moisture conditions by growing at a low rate, but are usually the first to be affected by drought. Trees in containers, along roadsides, on ledges or in shallow soil are also in locations prone to moisture stress and can also be considered drought prone. Trees whose roots are shallow because of high water tables, such as trees next to rivers and lakes, are also quite susceptible to drought when the water table falls. Often it is the tree nearest bodies of water which, ironically, are the first to die in a severe drought.

One of the most common symptoms of moisture stress in trees is leaf scorch. This symptom involves the browning of the leaf margins of broadleaf trees and of the needle tips of conifers. Another common symptom of moisture deficiency in trees is interveinal necrosis. The leaf tissues around the major veins remain green, but the tissue between the veins turns brown. For more information on leaf scorch and interveinal necrosis, see page 54.

If moisture deficiency exists for more than one season in trees, crown decline will usually begin. Dieback of twigs and small branches in the upper crown usually occurs first and, later, progressively larger branches are killed. Sucker growth may also appear on the main trunk and large branches of some species. There is often a delay between the drought period and the time of symptom expression that causes problems in diagnosis of moisture stress. Since water deficiency may cause extensive root injury in late summer and fall, the current year's foliage may not reveal any symptoms. However, the effects of the

previous year's drought may occur on trees the following year, when rainfall may be normal. It is therefore important to be aware of yearly trends in rainfall.

The symptoms of moisture stress in trees usually do not appear until late in the summer after extensive periods of hot and windy dry weather. Treatment for moisture stress, however, should begin in advance of symptom expression. In many species, particularly the conifers, drought symptoms indicate a tree already is in dangerously poor health.

Although no trees are immune to drought, those growing in the forest or in forestlike conditions are more resistant to moisture stress than trees growing along streets and with lawn over their roots. Trees with unrestricted root space and trees with their roots covered with natural or added mulches are least likely to suffer from periods of low precipitation. Not all trees, of course, can have these ideal conditions because the environment of our roadsides, where trees are needed most, cannot be changed back completely into a forest setting. It is possible, however, to modify the roadside environment by adding thick mulches around newly planted and existing trees to minimize moisture stress and by planting clumps of trees or wide tree belts that can create forestlike conditions.

If road widening and sidewalk straightening and levelling could be avoided, large numbers of existing shade trees would be saved from the loss of even more root area. Select tree species that can adapt to limited moisture and avoid rapid-growing trees that soon outgrow their available root area. This practice would decrease the moisture stress problem on shade trees along roadsides. Similar problems exist in privately owned yard trees but, in this case, watering of a few trees can correct the problem. Watering should be done over roughly a 12-hour period with a slow running hose that is periodically moved to thoroughly wet down the entire root zone to a minimum depth of 30-50 cm.

Winter Drying. - Evergreens are subject to loss of water during the winter. Since the soil around the roots is normally frozen, water lost through transpiration at this time cannot be replaced. The phenomenon of winter drying is discussed in more detail under "Browning of Evergreens" on page 32 of this pamphlet.

b. Water Excess

Flooded and Saturated Soil. - The roots of most plants are obligately aerobic and need gaseous exchange of oxygen and carbon dioxide between the air and the soil for them to survive. The concentration of oxygen in the air aboveground is usally about 21%. The oxygen must diffuse into the soil to reach the roots. Oxygen is usually in slightly lower concentration (10-21%) in the well-aerated soil than in air, but oxygen concentration drops abruptly to about 1% near the water table. The roots of most plants are injured whenever the oxygen concentration drops below 10%, and root growth stops entirely at concentrations below 3%. When water stands over the roots or the soil becomes saturated for

long periods during the growing season, gaseous exchange cannot take place between roots and air, and soil conditions become anaerobic. The roots suffocate under these conditions and most plants will soon begin to decline and die. The effects on a plant of any given period of inundation or soil saturation will vary with the species, time of year and duration of suffocation stress. In general, the effects of water excess: 1) will be greatest during the growing season, 2) will be directly related to the duration of the stress, and 3) will occur most quickly on species not tolerant to natural flooding.

The best way to avoid problems with excess moisture is to determine the soil moisture and drainage patterns of an area. Avoid planting in areas that pool water after rains or that are flooded in the spring. It may be possible to change or improve drainage patterns to eliminate flooding or saturated soil. This is especially recommended in areas where the natural drainage patterns have been altered by construction or by other activities of people. In some cases, "water loving" plants can be situated in areas subject to flooding (Table 1).

Table 1. Tolerance of various tree species to wet sites and occasional flooding.

Tolerant	Intolerant
Ash	Paper birch
Cottonwood	Red oak
Elm	Blue Spruce
Poplars	White spruce
River birch	Sugar maple
Silver maple	
Willows	

Overwatering. Since proper watering involves the saturation of the soil to a depth of at least 30 cm, several days are required for the roots to absorb the water and for excess water to drain away from the roots. If the soil is kept saturated by too frequent watering, the roots will suffocate from lack of oxygen. Excessively wet soil conditions also favor the attack of root disease fungi.

3. EROSION

Loss of soil around roots of trees due to erosion is a common problem on steep grades and near bodies of water. Undercutting of banks, with subsequent blow-down of adjacent trees, is a common result of erosion. Whenever a hillside must be disturbed for a house or road, the new bank must be restored to a stable angle. Ground vegetation should be established as soon as possible to retain soil around the remaining trees. Trees growing near water present a special problem since they have developed shallow root systems from growing near the high water table. These trees should be protected from shoreline erosion by placing a breakwater in front of exposed trees.

4. PHYSICAL DAMAGE FROM WIND, SNOW AND ICE

Although wind storms cannot be prevented, damage could be avoided by preventing weak forks which are the most common cause of branch and trunk failure. Weak forks arise from branches growing at such an acute angle that normal wood formation is inhibited and a structural weakness occurs. Weak forks can be eliminated either early when the tree is small or secured by placing a support between the forks. Tree species such as silver maple which are prone to weak forks should be avoided in locations near roads, buildings and utility lines. The extra weight of snow and ice can also damage trees. As for wind breakage, prevention of weak branch structures is the only practical way to minimize the occurrence of this type of injury.

Small trees and shrubs growing close to buildings can be severely injured from falling ice and snow. Steps should be taken, in cases where the danger is apparent, to protect valuable foundation plantings by placing some type of strong lattice over them during the winter months.

Trees can also be injured by hail. The force of large hailstones causes injury to the top side of the branches. Severe hail injury may girdle branches or break them off if they are small-sized.

5. LIGHTNING INJURY

Electrical discharges (lightning) during storms occasionally strike shade trees. Those in exposed locations such as open fields or on hilltops or trees above the forest canopy are most commonly struck. Injury from lightning is variable, ranging from the explosion or burning of the entire tree to minimal damage to the trunk and roots. In many cases, however, when only minor injury is evident on the trunk, considerable damage has occurred to the roots. The roots of a tree that has been struck with lightning should be inspected for extent of injury before therapeutic treatments begin. If more than 50% of the root system appears healthy, prompt therapy may help the tree to recover. Trees injured by lightning should be treated similarly to other stressed trees. Loose bark should be removed and injured bark cut back to healthy tissue. The injured tree should be fertilized with compounds low in nitrogen but high in phosphorus and watered during dry spells. Frequently, trees may be subject to repeated strikes due to their exposed location and, in these cases, installation of lightning protection is recommended. Lightning protection for trees is similar to the lightning rods that protect buildings. A copper cable is placed as high as possible in the tree and fastened with copper nails to the trunk all the way down the tree to the ground. The end of the cable is attached to a ground rod driven deep into the soil. This system like all devices attached to living trees, should be checked periodically and adjusted to allow for growth and expansion of the tree.

HERBICIDE INJURY

Herbicides or "weed killers" are chemicals which can cause the death of both woody and herbaceous plants. These chemicals are quite useful in controlling undesirable plants in and around agricultural crops, in recreational areas and around homes. When used properly, herbicides are effective and only kill the target plants. In recent years, however, widespread applications of herbicides has often resulted in their misuse with subsequent injury to non-target plants.

Injury from herbicides on plants is influenced by a number of factors such as the material used, the rate of application, the time of application, the species of plant and the temperature. Injury can occur from direct contact of materials on all above-ground parts of the plant or through root absorption and translocation.

Most herbicides can be classified as one of the following: pre-emergence, contact and soil sterilant.

Preemergence Herbicides. These materials are used most commonly on lawns to prevent the growth of weeds, particularly quackgrass. They are usually available in granular form, either alone or in combination with fertilizers, and are normally applied with a lawn spreader. As a group they are low in toxicity and most can be used safely on turf around trees and shrubs. Injury, however, has been found with high rates of simazine and dichlobenil. The most common symptom of injury from these herbicides is a narrow chlorotic band around the entire leaf.

Postemergence Herbicides. These herbicides are applied to undesirable plants that are already established. They fall into two general groups: 1) those that act like plant regulators or hormones and 2) those that do not.

Hormone-type herbicides are chemicals that closely resemble the structure and, therefore, the mode of action of certain plant hormones. The most common of these materials are 2,4-D and 2,4,5-T, both of which closely resemble auxin (indoleacetic acid). Some other commonly used hormone-type herbicides are silvex, MCPA and dicamba. Although there is a large number of hormone-type herbicides, their mode of action and consequently their effect on plants are similar. These materials all cause abnormal growth of plant parts. Some common symptoms are curled leaves, twisted petioles and distorted shoots and twigs. Some of these herbicides (e.g., 2,4-D) break down as soon after application, while others (e.g., dicamba) may persist in soil for long periods. Persistent materials are most likely to move downward into soil and injure roots of woody plants.

Non-hormone herbicides do not resemble the chemical structure of plant hormones, but disrupt essential steps in metabolism and thereby cause injury of death. One example of this group is aminotriazole, which blocks chlorophyll synthesis and causes foliage to turn white to pinkish-white. The affected plant cannot utilize the energy from sunlight without chlorophyll and subsequently dies. Another common herbicide of this type is dalapon. Both aminotriazole and dalapon are

translocated from roots to the leaves and are termed systemic herbicides. Injury can occur, therefore, in the upper parts of trees following application of a systemic herbicide to an undesirable plant growing near the periphery of the root zone.

Contact Herbicides. Contact herbicides are similar to the non-hormone herbicides in their mode of action but produce rapid killing of plant tissues on contact with little translocation. These herbicides are usually not applied near trees or shrubs but may cause injury from spray drift. Injury will usually appear as small necrotic spots where drift contacts foliage. One herbicide in this group is paraquat.

Soil Sterilants. Chemicals applied to soil that kill all living organisms are known as soil sterilants. They may be volatile liquids or gases that do not persist in the soil, or they may be long-lasting chemicals. Temporary soil sterilants are most commonly used prior to planting in nurseries and in various other agricultural operations. Sterilants are sometimes used to treat soil suspected of containing infectious root disease organisms. Soil sterilants are also used to prevent pathogen spread via root grafts in trees. Temporary soil sterilants escape from the soil as gases and the treated area can usually be planted in a few days after application. These materials can kill roots while in the soil and caution must be exercised during application near existing trees. Some common materials in this category are Vapam, methyl bromide and Vorlex. Semipermanent herbicidal soil sterilants can continue to cause considerable root injury to plants long after they are applied and can be carried by surface water to cause injury to surrounding plants. Some common materials of this type are atrazine, borate-chlorate mixtures, bromacil, diuron, karbutilate, monuron, prometryn and simazine. These soil sterilants are quite toxic to most trees and ornamentals and their use near these plants is not recommended.

Diagnosis of Herbicide Injury. Injury from herbicides is difficult to diagnose accurately and usually requires more than symptom recognition on injured plants. Many noninfectious and some infectious diseases can cause symptoms that appear similar to herbicide injury. There are, however, typical patterns of injury that are most commonly associated with herbicides, such as twisted and distorted leaves. Injury of a similar type to several species is usually a good indication of herbicide damage, but such injury is not necessarily restricted to herbicides. History of herbicide use in a location is also essential information in helping diagnose injury. However, this information may not be readily available and may even require a little detective work by the investigator. Herbicides are sometimes combined with other materials, such as fertilizers, to obtain "weed and feed" mixtures, and the applicator may not be aware of the exact nature of the materials that were used. In certain cases, an investigator may be able to determine the offending material by reading the label of a container if one is available. Also check the amounts and mixtures (if any) used, the weather conditions during application and the exact areas treated. Determine if there are any areas near the site of injury that are not routinely treated with herbicides, such as around power lines, railroad and highway rights-of-way, and certain commercial installations. Any

areas of open ground that are conspicuously "weed free" have most likely been treated with herbicides. This type of information will also be invaluable in attempting to diagnose other forms of chemical injury.

Preventing Herbicide Injury. Most herbicide injury can be prevented merely by following directions on the label. Avoid excessively high application rates and exercise care in application to avoid non-target plants with spray and spay drift. Drift can be minimized by spraying only during periods of relative calm, by using coarse sprays or foams to avoid fine droplets, and by keeping spray nozzles as close to the target plant as possible. Equipment used for herbicide application should not be used for other purposes such as fungicide, insecticide or fertilizer applications. If this is not possible, application equipment must be thoroughly cleaned before other materials are used. Avoid excessive applications of persistant herbicides that may build up in the soil. Re-apply such materials only when weeds reappear.

Remedying Herbicide Injury. When injury has occurred from herbicides it may be found in a range from mild injury requiring no treatment to the rapid killing of the plant in severe cases. Before any therapeutic treatment can begin it must be known whether the injury came from a foliar spray or from soil applications and whether the herbicide is persistant or nonpersistant. If the herbicide is nonpersistant it can be assumed that no further injury will occur and treatments can be aimed solely at helping the plant to recover. If, however, the herbicide is persistant then efforts must also be made to detoxify the soil to prevent further injury. Most herbicides can be detoxified with activated charcoal applied over the roots and worked into the soil. The amount of charcoal needed to detoxify the herbicide is related to amount of active ingredients applied. Minor foliar injury generally does not require treatment, but defoliation of severe foliar injury may cause considerable stress. Application of a balanced fertilizer in the spring will help the plant to replace nutrients lost through foliar injury. Root injury to trees from herbicides should be treated like other forms of root injury with branch thinning and phosphate fertilizer application to encourage root growth. Although herbicide injury may often appear severe, especially on foliage, many trees recover and resume normal appearance during the next growth season. Herbaceous ornamentals, however, may not recover from herbicide injury as readily as trees.

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August, 1980

Alberta AGRICULTURE

Garden Fax

HIGH SALT CONTENT IN GARDEN SOIL

Salts are a common and natural constituent of all soils. Normally, these salts are present in low amounts in topsoil and plant growth is not affected. Accumulation of salts, through natural means or man's activities, can cause plant growth problems and result in poor growth or death of plants.

Salts can accumulate to high levels in field soils which are located in low lying and poorly drained areas. A white saltcrust on the soil surface often becomes evident when these soils dry out. Purchasing topsoil from such areas for use in the garden or flower bed should be avoided. Salts can also accumulate in soil through improper care and management practices. Excessive fertilization or watering with high salt-containing waters are two of the most common ways of causing or aggravating an existing salt problem in soil. The salt content of well water should be analyzed prior to its use as an irrigation water source. It is also possible to induce a salinity problem through very heavy additions of soil amendments which have high salt content e.g., manure, gypsum.

Salts are a permanent constituent of soil. Once the salts have accumulated in a soil, there is no chemical treatment which will remove or counteract their adverse effects on plant growth. Special management practices become necessary in order to successfully grow plants on soils with high salt content. Some recommended practices are as follows:

Provide Adequate Drainage

Digging shallow ditches or trenches to remove surface runoff water will help to reduce salt content in soil and prevent further accumulation. The runoff water will carry away dissolved salts which would otherwise be deposited on the soil surface when the soil dries out. Providing subsoil drainage through installation of perforated plastic pipe or ceramic tile is considerably more difficult and costly but can also be used to prevent further salt build-up by intercepting and removing saline water.

Grow Salt Tolerant Plants

Plants differ widely in their tolerance of high salt content in soil. The growth of some plants may be seriously reduced when grown in high salt containing soil, while more salt tolerant plants such as beets or spinach may only be slightly affected. The relative salt tolerance of some commonly grown vegetables is shown in Table 1.

Table 1 — Relative Salt Tolerance of Vegetables*

High Salt Tolerance	Medium Salt Tolerance	Low Salt Tolerance
12 mmhos	10 mmhos	4 mmhos
Beet	Tomato	Radish
Kale	Broccoli	Celery
Asparagus	Cabbage	Bean
Spinach	Pepper	
	Cauliflower	
	Lettuce	
	Corn	
	Potato	
	Muskmelon	
	Carrot	
	Onion	
	Pea	
	Squash	
	Cucumber	
10 mmhos	4 mmhos	3 mmhos

*Relative salt tolerance decreases down each column, e.g., tomato is more salt tolerant than cucumber.

Salt content of soil can be measured accurately in the laboratory. Table 1 gives the salt level in soil, measured in mmhos[1], at which a 50 percent reduction in plant growth occurs. For example, tomatoes would

[1]A mmho is a commonly used measure of salt concentration in soil. A nonsaline soil normally has less than 1 mmho.

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produce half as well in a soil having a 10 mmhos test as they would in a nonsaline soil (less than 1 mmho). Similarly, cucumbers would do half as well in a soil having a test of 4 mmhos as in a nonsaline soil.

The first and most common symptom of salt injury is a reduced rate of plant growth. A plant growing on saline soil is smaller than normal, may have darker leaves than normal and will wilt from drought sooner than it would in a nonsaline soil. As salinity increases plant growth will cease. Leaf burn, commencing at the tip, will occur with ultimate death of the plant in highly saline soil.

Maintain Adequate Soil Moisture

Salts are most damaging to plants when the soil is dry. For this reason, any means of maintaining or replenshing soil moisture content will help to avoid salt damage to plants. Infrequent heavy watering is recommended for saline soils rather than frequent light waterings. Heavy watering will help to dissolve salts and leach them down and out of the plant rooting zone. Incorporation of low salt containing organic matter such as peat, compost or grass clippings will also help to reduce the injurious effects of salts because the soil will be able to hold more water and salt concentration will thereby be diluted. High salt containing manures should not be used as an organic amendment for saline soils.

A soil test provides an accurate way of determining the amount of salt in a soil. From the soil test results and knowledge about the relative salt-tolerance of plants one can then select the most suitable kind of vegetable for a particular soil. Other management practices such as providing better drainage, timely watering and addition of organic material can also be used to minimize salt injury and allow a wider range of garden vegetables to be grown.

MISCELLANEOUS ENVIRONMENTAL STRESSES

1. Building and Road Construction

Trees, like people, are easily disturbed by changes in their surroundings. Construction of buildings and roads is a major cause of tree injury.

Symptoms of tree disease may not be immediately visible. Sometimes several years of decline occur between injury and death. Trees are often injured by earthmoving equipment and by changes in ground level. Roots can be injured when heavy equipment passes over them. Ditching along highways and in building projects can also injure trees. Root injury, not trunk injury, during construction is most likely to kill trees.

The addition of asphalt, concrete bricks or more than a few inches of soil around trees will change roots. Trees with roots so covered have trouble "breathing" and may die within 3 to 5 years. The construction of a small well around the trunk of an established tree may not always protect it. A young tree planted in a large well can adapt to living in a well and will usually grow to maturity. When young trees are to be planted within large paved areas, such as parking lots or pedestrian plazas, they should be planted in large wells that have been carefully planned and constructed. Trees should not be planted until all construction has been completed.

2. Soil Compaction

Soil compaction around trees is often caused by people, pets, bicycles and cars in parks and other recreation areas as well as in heavily used areas surrounding public buildings, business centers and multi-unit residential dwellings. Injured, exposed tree roots are hazardous to trees and to people. Compacted soil cuts off water and oxygen to tree roots. Dying leaves on mature trees and dying branches on young trees may indicate compaction injury.

3. Lawn and Garden Equipment

Lawnmowers, snowplows, and other lawn and garden equipment can severely injure trunks, branches and roots of trees. These injuries can be as serious as those caused by heavy construction equipment. To prevent accidentally injuring young trees with lawn mowers, grass should be kept away from the tree trunks.

4. Deicing Salt

Deicing compounds used on highways, driveways and sidewalks in winter contain sodium chloride (table salt) and/or calcium chloride. These chemicals are toxic to trees. Roadside trees are injured when salt is absorbed by their foliage and roots. The relative tolerance of various trees and shrubs to deicing salt is given in the table below.

AERIAL SALT SPRAY TOLERANCE OF LANDSCAPE PLANTS

*(For soil salt tolerance ratings see designation after plant name.)

Sensitive	Intermediate	Tolerant
Deciduous Trees		
Celtis occidentalis Hackberry	Acer ginnala Amur Maple	Acer plantanoides (I) Norway Maple
Crataegus spp. Hawthorne	A. negundo (I) Boxelder	A. saccharinum (I) Silver Maple
Malus spp (I) Crabapple	A. saccharum (S) Sugar Maple	Elaeagnus angustifolia (T) Russian Olive
Prunus serotinia (T) Black Cherry	Amelanchier alnifolia Saskatoon	Fraxinus americana (T) White Ash
Quercus alba (T) White Oak	Betula spp. (I) Birch	Gleditsia triacanthos (T) Honeylocust
Q. rubra (T) Red Oak	Fraxinus pennsylvanica Green Ash	Juglans nigra (S) Black Walnut
Tilia cordata (S) Littleleaf Linden	Pyrus spp. Pear	Populus spp. (I) Poplar
	Quercus macrocarpa (T) Bur Oak	Sorbus decora Mountain Ash
	Tilia americana (S) American Linden	
	Ulmus americana American Elm	
Shrubs		
Berberis thunbergii (S) Japanese Barberry	Alnus rugosa (S) Speckled Alder	Caragana arborescens Siberian Pea Shrub, Caragana

* Soil Tolerances - (S) - Sensitive; (I) - Intermediate; (T) - Tolerant.

Cornus spp.
Dogwood

Euonymus europea (S)
European Euonymus

Sambucus canadensis
American Elder

Spiraea spp. (S)
Spirea

Viburnum lantana (S)
Wayfaring Tree

Juniperus horizontalis
Creeping Juniper

J. h. 'Plumosa' (I)
Andora Creeping Juniper

Lonicera spp. (I)
Honeysuckle

Syringa vulgaris
Common Lilac

Viburnum dentatum (S)
Arrowood Viburnum

V. lentago (S)
Nannyberry

V. trilobum (S)
High Bush Cranberry

Euonymus alata (S)
Winged Euonymus

Juniperus chinensis 'Pfitzerana' (T)
Pfitzer Juniper

Philadelphus spp.
Mockorange

Rhamnus spp.
Buckthorn

R. typhina
Staghorn Sumac

Ribes alpinum
Alpine Currant

Rosa rugosa
Rugosa rose

Symphoricarpos albus
Snowberry

Syringa reticulata
Japanese Tree Lilac

Tamarix ramosissima
Five-Stamen Tamarix

Coniferous Trees

Abies balsamea (I)

Balsam Fir

Picea glauca (I)
White Spruce

Pinus resinosa (S)
Red Pine

P. strobus (S)
Eastern White Pine

P. sylvestris
Scotch Pine

Taxus spp.
Yew

Thuja occidentalis (I)
American Arborvitae

Juniperus spp.

Juniper

Picea abies (S)
Norway Spruce

Pinus ponderosa (I)
Ponderosa Pine

Pseudotsuga menziesii (S)
Douglas Fir

Juniperus virginiana (T)
Eastern Red Cedar

Larix decidua (S)
European Larch

Picea pungens (S)
Colorado Spruce

Pinus banksiana
Jack Pine

P. nigra
Austrian Pine

Misc. Environmental Stresses (cont'd)

5. Wounds

Wounds commonly occur on the exposed parts of trunks and roots. Although tree wounds are often caused by the forces of nature, people are also responsible for many root injuries, bark injuries and broken limbs. Unfortunately, some people enjoy carving designs and words into the bark of living trees. These carvings mar the tree's beauty and open its trunk to invasion by a variety of microorganisms. Trash fires or campfires built against the trunk of a tree cause injury and may kill the tree. Improperly treated wounds are often followed by decay.

NUTRIENT DEFICIENCIES

NUTRIENT	SYMPTOMS OF DEFICIENCIES
Nitrogen	- Plants grow poorly and usually are light green in color. Lower leaves turn yellow or light brown and the stems are short and slender.
Phosphorus	- Young leaves are bluish-green with purple tints. The lower leaves sometimes turn light bronze with purple or brown spots. Shoots are short and thin, upright and spindly.
Potassium	- Plants have thin shoots. Dieback may occur in severe cases. Older leaves may show slight chlorosis with typical browning of the tips, scorching of the margins and many brown spots, usually near the margins. Leaves may gradually roll upward and inward.
Magnesium	- Older leaves are thin. The younger ones become mottled or chlorotic, followed by reddening and sometimes appearance of necrotic spots. The tips and margins of leaves may turn downward and inward so that the leaves appear cupped. Defoliation may follow.
Calcium	- Young leaves become distorted with the tips hooked back and the margins curled. New leaves may fail to to unroll. Often the leaves are irregular in shape and ragged with brown scorching or spotting at the margins. Terminal buds eventually die if the deficiency is severe. Affected plants have poor root systems.
Sulphur	- Plants have pale green or light yellow colored young leaves without spot formation. Symptoms may resemble those of nitrogen deficiency.
Boron	- Bases of young leaves of terminal buds become light green and finally break down. Stems and leaves become distorted. Fruit may crack on the surface or rot in the center.
Zinc	- Leaves may initially show chlorosis, then later develop necrotic areas and show purple pigmentation. Leaves are few and small with short internodes. Fruit production is usually poor.
Manganese	- Leaves may exhibit a pattern of chlorosis somewhat between that of manganese deficiency and iron deficiency. Symptoms may appear on any or all mature leaves.

Copper - Characterized by early cessation of terminal growth and partial dying back of terminal shoots. Buds growing out below dead areas may give rise to a witches' broom symptom. Leaves may be mottled, chlorotic and necrotic.

agri-fax Alberta AGRICULTURE

Agdex 532

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IRON DEFICIENCY IN PLANTS

GENERAL

Under certain soil conditions, iron deficiency may occur in fruit trees, ornamentals and other plants. Although iron is the most abundant of the trace elements, the availability of iron in the soil may be low. As yet there is no suitable soil test for iron, as there is for the major nutrients. Diagnosis of iron deficiency, therefore, rests on identifiable plant symptoms plus a knowledge of the history of the soil.

FACTORS ENCOURAGING IRON DEFICIENCY

- Excess lime in the soil, "lime-induced chlorosis"
- High soil pH (above 8.0)
- Bicarbonate ions in the soil or irrigation water
- Excess amount of phosphates in the soil
- Excess soil moisture and low soil temperatures
- Excess quantities of metallic ions such as copper and manganese which may occur in acid soils

SYMPTOMS

Iron deficiency is characterized by chlorosis (yellowing) of the younger leaves of many species. The tissue between the veins gradually turns yellow while the veins tend to stay green. The conditions may advance throughout the entire plant if unchecked and the tips and margins of some leaves may turn brown and become dry and brittle. In severe cases and with certain species, the new leaves may lose all their green color and appear straw-colored.

Plant species vary in their susceptibility to iron deficiency:

Susceptible	**Relatively Tolerant**
Raspberry	Russian Olive
Mountain Ash	Lilac
Spiraea	Cotoneaster
Apple	Spruce
Currant	Barberry
High Bush Cranberry	
Elder	

IRON DEFICIENT LEAVES

Network of veins usually retain their green color while areas between veins become chlorotic.

Conifers such as pine, fir and juniper are less susceptible but may show general needle yellowing on the upper or youngest clusters. Iron deficiencies rarely occur in forage grasses or legumes. Cereal crops may show an intervenal chlorosis or striping along the leaf. Lawn grasses may occasionally show iron deficiency because of high pH or high levels of lime or phosphate in the soil.

AREAS AFFECTED IN ALBERTA

Although iron deficiency may occur in localized areas throughout the province depending on the factors noted above, the condition is most likely to show up in susceptible species growing on high lime or calcareous soils. These soils are found mainly in southern Alberta, primarily in the Brown Soil zone. The closer the lime layer to the surface, as in the case of eroded soils, the greater is the likelihood of induced iron deficiency. In southwestern Alberta there is a wide band of high lime soils extending south of Calgary through the Claresholm area to Fort Macleod.

DIAGNOSIS

1. The application of a foliar spray of an iron-containing compound may be the best means of verifying the diagnosis (see below).

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2. Soil tests specifically for iron are not recommended, but they will determine factors such as pH and lime content which might be affecting the availability of iron to plants.
3. Plant analysis for iron content is of limited value. Soil dust on the sample may be a serious source of iron contamination. Also, plants showing iron chlorosis induced by high levels of phosphorus generally have a normal concentration of iron in the tissues. Such iron, however, does not appear to be readily available to the plants.

TREATMENT

Soil treatments for iron deficiency are not always successful since the same factors that limit the availability of soil iron also render added iron unavailable to plants. The use of foliar sprays and chelated iron compounds, however do offer some promise. When deficiencies exist, iron-chlorotic leaves should begin to "green-up" within ten days after application of iron.

In the case of greenhouse crops particularly, proper adjustment of the pH of the growing medium is often the best preventive treatment. For example, azaleas are grown in a medium-high acid peat which helps to ensure the availability of iron to meet the high iron requirement of these plants.

Soil Application of iron salts, particularly on calcareous soils, is not recommended unless chelated products are available. The chelate resists efforts in the soil to render its iron unavailable to plants.

For trees and shrubs, soil application is most effective if the chelate is applied to the soil and watered in around the base. For potted plants the iron may be dissolved in water and applied as a soil drench.

Iron compounds may be purchased from garden supply centres. A range of package sizes is available. The iron may be in chelate or micronized form and varies in concentration from product to product. As a result of this, general application rates cannot be given here. Purchasers should follow the information supplied on the product label.

Foliar Sprays of iron salts have been used successfully. A 1–2% solution of ferrous sulfate (0.5–1 kg per 45 L of water) may be applied to iron deficient plants. One litre per 20 square metres, or on a field scale, 170–225 L per acre should be adequate. The addition of a wetting agent: i.e. several drops of a mild detergent per gallon is essential.

Iron chelates can also be used in foliar sprays instead of soil applications.

CONCLUSIONS

It should be noted that foliar applications of any iron compound bring about temporary correction of iron chlorosis in a plant, but only by correcting the soil conditions responsible can permanent recovery ever be obtained.

The most practical solution to "lime-induced" chlorosis is learning to live with it and to recognize that a causative factor that induces lime chlorosis may not easily be removed once it is established in a soil. This means that steps should be taken to alleviate, not aggravate, the condition and plant species should be selected which are resistant to iron chlorosis.

Metric Conversion

1 pound X 0.45 = 1 kg
1 gallon X 4.5 = 1 litre
1 square foot X 0.09 = 1 square metre

II. EVERGREENS

CYTOSPORA CANKER

See "Cytospora Canker" in Section III, DECIDUOUS TREES, Page 48.

DWARF MISTLETOE

Dwarf mistletoes are plants that lack true leaves and contain only primitive leaves called bracts. These structures are unable to manufacture sufficient food via photosynthesis to meet the energy needs of the dwarf mistletoe plant, and most of its energy needs as well as water and minerals are supplied by the host tree. Because of this heavy reliance on the host tree, the dwarf mistletoes cause a great deal of damage to both forest and shade trees. Much of the tree's reserves are diverted by the infecting dwarf mistletoe plants and the host trees slow in growth and eventually decline and die.

PATHOGEN: *Arceuthobium* spp.

HOSTS: Dwarf misteltoes are restricted to coniferous hosts and many conifers in North America are susceptible to at least one species of dwarf mistletoe. As a group, they are most prevalent in the western United States, western Canada and Mexico and cause problems on ponderosa pine, lodgepole pine, Douglas fir, true firs, western larch, spruces and many other native conifers. In the northeastern United States and eastern Canada black spruce is the most common host, although white spruce is occasionally infected.

SYMPTOMS: Infected branches increase in thickness. When compared at the base with the uninfected branches on the same growth whorl, infected branches appear distinctly swollen. Large numbers of smaller branches called witches' brooms are often formed on the infected branches. Broomed branches usually have dense foliage, outlive the noninfected branches around them and continue to enlarge. Dwarf mistletoe aerial shoots form at sometime during the enlargement of infected branches and are quite easy to recognize. Infections on small trees may result in rapid mortality. Large trees decrease in growth and progressively decline as witches' brooms develop. The foliage at the top of the trees becomes short, sparse and yellowish, and the upper crown begins to exhibit dieback. After an indefinite period of declining growth, the entire tree dies, either as a result of the dwarf mistletoe parasites or due to the inability of the tree to prevent the invasion of weak parasites due to its low vigor. Infected broomed branches are frequently the last to die.

DISEASE CYCLE: The aerial shoots of the dwarf misteltoe plants bear the flowers. Male and female flowers are produced on separate plants. During the mid to late spring, male flowers produce pollen that is usually carried to female plants by insects. It takes approximately a year for

the fruit to reach maturity. When mature, the fruits are oval berries that vary in size and color depending on the species of dwarf mistletoe. Each berry contains a single seed; in mid-summer, the mature seeds are dispersed by "explosive discharge". Water pressure that has built up inside the berries during maturation propels the discharged seed at high velocity (approximately 27 m/sec) to a maximum horizontal distance of about 16 m. The seeds are coated with a mucilaginous substance known as viscin and are able to adhere to most objects they contact in flight. Many of the seeds contact needles of adjacent trees, while others contact branches, trunks or land on the soil. The seeds on the needles remain attached where landed until a rainy period. Their mucilaginous coating absorbs water, swells and becomes slippery. The seeds slide down the needle until they reach the twig and then adhere to the bark. Although infection is most common on small branches and twigs, older branches may occasionally be infected. The seeds of dwarf mistletoes remain dormant and germinate in the spring, with the exception of those species on ponderosa pine which germinate within a month after dispersal. The root from the germinating seed grows until it reaches a suitable location for penetration of the host, forms a support structure (holdfast) and grows into the host bark. Once the root reaches the living tissue in the inner bark it begins to branch out into a complex root network inside the bark and outer wood known as the endophytic system. This root system continues to enlarge throughout the infected branch and eventually may reach the main stem. Aerial shoots are usually produced 3-5 years after infection. Male and female plants usually reach sexual maturity 4-6 years after infection.

CONTROL: Dwarf mistletoes are most effectively controlled by removing severely infected trees and by eradicating the pathogen in light to moderately infected trees by pruning. The most critical area to begin a sanitation program in a park, recreation area, residential area or backyard is in the overstory. Infected trees in the overstory will result in the spread of the dwarf mistletoe seeds to the smaller understory trees below. Overstory trees should be removed if more than one half of their branches or most of their upper crowns are infected. Trees less severely infected should be pruned of all infected branches. Pruning cuts should be made at the trunk. When heavy pruning is necessary on a portion of the tree, isolated branches should not be left because they often contain latent infections. It is also recommended that, where the aesthetic value of the infected tree would not be damaged severely, two or three whorls of branches above the highest infected branch also be cut as well as all lower branches. This practice will decrease the necessity of the arborist to

make follow-up pruning cuts if latent infections are present. However, infected trees should be watched for appearance of new infections each year. Remove infections as they appear.

Although heavily infected trees usually cannot be completely rid of infections, pruning can often help restore the vigor and prolong the life of valuable shade trees, particularly when combined with a program of watering and fertilization. When infection of understory trees is not a prime concern, heavily infected shade trees in the overstory therefore need not be removed if they are valuable ornamental trees. Trunk infections, although apparent indicators of extensive infection, are usually not serious on trees over 13 cm diameter because the endophytic system of the dwarf misteltoes spreads slowly in the main stem of larger trees and seldom results in mortality. On much smaller trees (under 5 cm diameter), however, the chances of mortality from trunk infections is much higher. Trunk infections may appear around pruning cuts where infected branches were removed. In these cases, the endophytic system may have extended into the main stem before the infected branch was cut, but these infections are generally not serious in larger trees.

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Alberta AGRICULTURE

Garden Fax

BROWNING OF EVERGREENS

Needle coloration is a sign of illness in coniferous evergreens. The illness or injury may be in the needles, but can also be in the roots, trunk or branches. The crown can appear slightly or distinctly yellow, straw-colored, brown, grey-brown or red-brown depending upon the severity of the damage. The color change is definite and sometimes quite spectacular, and can mean that there is something wrong. Often the change occurs long after injury, so that recovery may not be possible.

Although color change is a good clue, other symptoms have to be taken into account for diagnosis and control.

Autumn Needle Shed

Old foliage of many conifers, brown and shed during autumn. These are two and three year old needles, depending on the species. The new growth and previous year's growth remain normal. This is a natural process, but is often confused with injury or disease. Most common on pines!

Frost Injury

In spring, new growing tips suddenly droop and get a blanched appearance, then turn brown leaving only the branch tips dead. The condition then progresses no further and the dead tips are shed, usually causing little harm to any but very small trees.

Herbicide Damage

Weedkillers tend to kill some but usually not all conifers in an area. Often, affected trees are browned completely during winter and then produce new growth at the tips when the growing season starts. This advent of green tips following severe crown discoloration is a common symptom of herbicide damage. Other symptoms indicate more specific groups of herbicides.

2,4-D and similar chemicals cause a curl, twist or distortion of new stems. Affected needles are often clumped together. Later needles become brown, but tend not to be shed immediately.

Atrazine and similar chemicals cause needles on the entire crown or whole branches to become very light yellow or white with some tip browning. Affected needles shed soon after symptoms appear.

Drought Damage

Trees gradually turn yellowish-green, then light brown from the top down and outside in until the tree dies. No insect or fungus will be found associated with these symptoms and ordinarily only individuals will be affected. Shallow rooted species particularly in irrigated areas or on sites with normally high water tables will be affected first. The absence of symptoms or indicators other than a gradually downward decline implies drought damage.

Cold or Winter Injury

At the advent of warm weather in the spring a sudden deep red-brown discoloration of branches or entire trees implies cold injury. The color fades to light brown during the summer. Most winter injury is caused by evaporation of moisture from crowns during sudden warm or windy periods in winter, rather than extreme cold. Particularly common in junipers, ornamental cedars, true firs, or any off-site ornamental.

Dog Damage

The foliage of outer, lower branches of ornamental small trees and shrubs, especially juniper, may become progressively yellow, then brown when neighborhood dogs use them as urinals.

Iron Deficiency

Foliage on a branch, part of the crown or more often the entire crown becomes distinctly yellow during several years. No insect or fungi are present, when severe dieback will occur. This is common in irrigated areas or in alkaline soils where iron is unavailable. Common in spruce, juniper and cedar.

Taken from: Bulletin 514, Idaho Agricultural Extension Service, "Why is my Evergreen Brown".

NEEDLE CASTS

PATHOGEN: *Lophodermella concolor*, *L. montivaga* and *Davisomycella montana* - lodgepole pine
Elytroderma deformans - lodgepole and Jack pine
Rhabdocline pseudotsugae - Douglas fir
Hypodermella laricis - western larch
Lophodermium pinastri - lodgepole and jack pine
Isthmiella crepidiformis - white spruce
Lirula abietis-concoloris and *L. mirabilis* - alpine and balsam fir

SYMPTOMS: Needle cast diseases are generally recognized by the presence of dark colored, spore-containing fruiting bodies of the causal fungi on infected needles. Affected foliage may have a reddish-brown discoloration only on portions of the needles. Healthy needles are often intermingled with diseased ones. Premature casting of needles is common. Depending on the pathogen present, needle casting may vary in severity from slight to serious. This disease is most important on young trees and seldom kills those beyond the seedling stage.

DISEASE CYCLE: Spores from fruiting bodies are spread by wind and splashing rain. Lopodermium discharges its spores from late summer to mid-autumn, while Rhabdocline and Elytroderma release theirs in the spring.

CONTROL:

1. Spray with Bordeaux mixture or copper oxychloride at the time of spore discharge. For Lophodermium needle cast of pine, use chlorothalonil applied every 2-4 weeks beginning in early in early November. For Rhabdocline needle cast of Douglas fir, apply sprays of mancozeb at 10-14 day intervals during April, May and early June.
2. Remove dying trees to reduce sources of infective spores.
3. Gather up and destroy infected needles, if practical.

NEEDLE RUSTS

PATHOGENS: *Chrysomyxa ledicola, C. empetri* and *C. ledi* - white, black and Engelmann spruce
Coleosporium solidaginus - lodgepole pine
Melampsora albertensis - Douglas fir
Chrysomyxa weirii - white and Englemann spruce
Pucciniastrum geoppertianum and *P. epilobii* - alpine and balsam fir

SYMPTOMS: Evergreen needles show small blisters which break open to expose masses of orange fungal spores. All of the current season's needles may be infected in some seasons. Due to their lesser amounts of foliage, young trees in the seedling or sapling stages are more likely to be detrimentally affected, especially when needles are killed. As rusts vary in intensity from year to year, mature trees are seldom defoliated or killed and more commonly experience a reduction in growth and vigour.

DISEASE CYCLE: Rust diseases are caused by fungi that grow only on living plants. They are differentiated by the type of spores they produce and whether they form all of these on one or two species of host. All of the needle rusts discussed here have two alternating hosts. In addition to the evergreen host the following host(s) are required: *Chrysomyxa ledicola and C. ledi - Laborador tea (Ledum groenlandicum); C. empetri* - crowberry (*Empetrum nigrum*); *C. weirii* - wintergreen (*Moneses* sp. and *Pyrola* spp.): *Coleosporium solidaginus* - aster (*Aster* spp.) and golden rod (*Solidago* spp.); *Melampsora albertensis* - poplars (*Populus* spp.); *Pucciniastrum geoppertianum* - blueberry (*Vaccinium* spp.); *P. epilobii* - fireweed (*Epilobium* spp.). The complete life cycle of most needle rusts takes one year.

CONTROL:
1. Destroy alternate hosts in the vicinity of valuable evergreen plantings.
2. Bordeaux mixture can be applied as a protectant spray on evergreens, if desired.

SEASONAL NEEDLE YELLOWING

With the onset of autumn, homeowners and gardeners may observe yellow foliage on some of their evergreen trees, especially pines. The color change is often dramatic and a natural reaction is to suspect that a disease or insect has attacked the plant. While such attacks may cause foliage yellowing symptoms, they are not the major cause of the discoloration which occurs in autumn. Rather, the condition is natural senescence or "autumn shed" as any arborists call this phenomenon.

Evergreen trees appear throughout the year because they do not use all their foliage at one time. Annual leaf or needle drop often goes unnoticed because new growth conceals the old foliage on the inside of the tree that has turned yellow or brown. Leaf drop on evergreens usually takes place gradually, however, there are occasions when many leaves discolor simultaneously. Most species of spruce and pine and certain types of cedars and junipers shed their older foliage in autumn. Scots, lodgepole and Austrian pines retain their needles for 3-4 years, while spruce and fir keep theirs for a longer time. Pines occasionally drop a few of their three year old needles in late spring or early summer. Seasonal yellowing may not be visible unless one looks for it on the inner branches.

Any factor which decreases the vigor of an evergreen tree or places it under stress will bring about premature shedding. Some examples are wet or poorly drained soils, drought, transplant shock, poor fertility, spider mites, soil salinity, winter injury and herbicide damage. The implementation of appropriate remedial measures generally results in a resumption of normal growth, however, the inability of evergreens to regenerate lost foliage may leave the plants looking deformed and "scraggly" for several years. The advice of a specialist should be sought where possible confusion exists between seasonal yellowing of evergreens and various insect and disease problems.

WESTERN GALL RUST

PATHOGEN: *Endocronartium harknessii*

SYMPTOMS: Coniferous hosts are western hard pines: jack pine (*Pinus banksiana*), mugho pine (*P. mugo*), lodgepole pine (*P. contorta* var. *latifolia*, western yellow pine (*P. ponderosa*), Scots pine (*P. sylvestris*) and Austrian pine (*P. nigra*). The rust fungus stimulates the stem cambium to divide rapidly causing pronounced swellings. Infections generally remain localized and do not progress from branches into the main stem. Galls may persist for many years without killing branches; however, noticeable reduction of host growth often occurs. Masses of orange spores are released when the bark layer over the galls is ruptured. This is the most common and destructive stem rust of hard pines in Canada.

DISEASE CYCLE: Although reports suggest that this rust may also infect species of the figwort family (Scropulariaceae), it appears that no alternate host exists in western Canada. Thus, the disease is perpetuated on pines.

CONTROL:

1. Remove infected branches from trees.
2. Create a protective zone by removing trees with gall rust within 300 meters of healthy trees.
3. Avoid planting susceptible pines near diseased native stands.

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WINTER INJURY TO EVERGREENS

Regional Crops Laboratory, Olds

Needle discoloration in evergreens is sometimes a sign of winter drought or winter cold injury. Although winter cold injury and winter drought are not the only causes of browning in evergreens, they are the most common in most areas of Alberta.

WINTER INJURY

Generally, cold temperatures alone do not injure plant species that are adapted to a given area. Damage usually occurs when temperatures fluctuate excessively or rapidly.

The ability of trees and shrubs to withstand cold temperatures is dependent upon their winter hardiness. Winter hardiness is influenced by plant variety, soil drainage, location, natural protection, type of root system, and environmental conditions during the summer and fall. A cool summer followed by a warm, early fall with abnormally low temperatures in late October or early November may result in improperly hardened plants which are susceptible to freezing injury. Excessive application of nitrogen fertilizer, particularly in late summer and fall, will promote succulent growth that will not mature and may be damaged by freezing.

Root injury occurs most commonly during winters of little snowfall or in soils bare of vegetation. Plants with root systems damaged in the late summer by disease, insects, drought, etc. may be more susceptible to winter injury. Roots growing in poorly-drained soil are more likely to freeze than those growing in well-drained soil. This is especially true of pine roots. Damage to roots is seldom seen until the following summer, when plants may wilt and die.

WINTER DROUGHT INJURY

Winter drought injury occurs when the needles lose moisture more quickly than the roots can take it up. Since evergreens retain their needles throughout the winter, they lose moisture continuously and can easily become too dry. Plants on the south side of buildings or those exposed to drying winds when the ground is still frozen and the roots are unable to take up an ample supply of water are more prone to this type of injury.

Winter drought injury has several symptoms, depending upon the species of evergreen and the severity of the damage. In some species, the color of needles or leaves fades from green to a light tan or reddish-brown. Other species may exhibit brown and dried needle tips. If injury is severe, the shrubs or trees may lose most of the leaves or needles on one side or over the entire plant. Severe or complete defoliation of an evergreen means not only an unsightly appearance, but possible death of the plant later in the spring or summer.

PREVENTION OF COLD AND DROUGHT INJURY

- Use plant varieties recommended for the specific horticultural zones of the province (see the ***Alberta Horticultural Guide***, Agdex 200/01).
- Plant ornamental trees and shrubs in locations where the soil is reasonably well-drained.
- Water trees and shrubs, especially evergreens, before freeze-up to ensure that they have sufficient moisture in the root zone. This

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becomes critically important if a dry summer or fall has occurred. Pay special attention to plants which are situated under the overhang of houses. If warm weather occurs during the winter causing soil on the south exposure of buildings to become dry, water the evergreens in these locations.

- Avoid fertilizing trees and shrubs in the late summer or early fall. If fall application is desired, wait until trees or shrubs are dormant.
- Mulches of leaf mould, peat moss, chopped straw or other suitable materials around the base of trees and shrubs will increase moisture retention and decrease the depth of the frost line. They also prevent alternate freezing and thawing of soil after it is initially frozen. Mulches should be pulled away from the trunks of trees in the fall to allow the plants to harden off properly.
- Erect canvas, plastic, burlap or slat screens on the south and west sides of exposed evergreens to prevent desiccation. Burlap covering will also shade the plants and prevent excessive moisture loss. The screens should be at least two feet away from the trees. It is advisable to use plants that do not require this type of protection in severely exposed areas.
- Antidesiccant sprays applied in the fall provide evergreens with some protection from winter drought injury by reducing water losses during winter months.
- Deep-rooted evergreens are more resistant to winter drought injury than shallow-rooted evergreens as they are able to absorb moisture from further down in the soil when the surface soil is dry or frozen.
- Avoid poor planting locations. Trees and shrubs adjacent to white or aluminum-sided structures may suffer extreme damage. The reflection of the sun's rays from the structure to the plant increases the air temperature in the plant's microclimate. This condition causes moisture loss from the foliage above the level the plant is able to compensate for. Plantings in windy sites are liable to be damaged as well. Poorly-drained sites contribute to winter injury; therefore, avoid planting in low, poorly-drained soils.

Evergreens showing signs of cold and drought injury should be watered well as soon as the ground thaws. A light fertilization will help to promote new growth. Since injured trees are slow to begin growth, no pruning of branches or removal of trees should be undertaken until one can be sure which parts are dead. Careful pruning will be required to restore the shape and form of injured evergreens, especially pine and spruce.

III. DECIDUOUS TREES

ARMILLARIA (SHOESTRING) ROOT ROT

HOSTS: Shoestring root rot affects a wide range of shrubs and trees that are commonly used for ornamentals. It is a serious root disease in shade, forest and orchard trees all over the world.

PATHOGEN: *Armillariella mellea*

SYMPTOMS: The first observable symptoms of shoestring root rot can range from a slow gradual dieback to the sudden death of a tree. Examination of infected roots should reveal the presence of mats of fungus mycelium between the bark and the wood. These mats may extend to the buttress area and up the lower trunk. Strands of "shoestrings" composed of fungus mycelium are common of hardwoods and may form between the bark and wood, in decayed wood or around the outside of a root. The dark brown to black shoestrings are called rhizomorphs. In the late summer or early fall, honey colored mushrooms may appear around the base of infected trees. They only persist for a few weeks, but the black shrivelled remains of the mushrooms can often be found for many months.

The root bark is usually killed in advance of the mycelial mats. In conifers, resin flow occurs from infected roots and coats the bark. The wood beneath the mats may be decayed or sound. Decayed wood is moist, bleached and stringy. Considerable decay of large and small roots, as well as internal decay in the buttress area, is frequently associated with shoestring root rot. Bark killing eventually extends completely around the root buttress or lower trunk and girdles the tree. Many trees are subject to "windthrow" due to the loss of supporting roots.

DISEASE CYCLE: The fungus overwinters as rhizomorphs or vegatative mycelium in both living and dead trees. During the spring, the rhizomorphs and vegetative mycelium resume growth through the soil and infect healthy roots. Rhizomorphs enable the fungus to move from an infected tree to an adjacent healthy one, while vegetative mycelium primarily enables local infection spread within a tree's root system. After the infected tree is killed, the pathogen lives for many years as a saprophyte. In the late summer or early fall mushrooms produce large quantities of windblown spores. However, since this fungus has already been found in most soils worldwide, it is doubtful that these spores play an important role in the occurrence of this disease.

CONTROL:

1. The occurrence of shoestring root rot, in most cases, is related to previous stress on the tree. Prevention therefore depends to a large part on helping the tree avoid stress and remain as vigorous as possible.

2. Trees already infected with *A. mellea* should be relieved of continuing stress and made as vigorous as possible with regular fertilization and watering. Severely infected trees should be removed.

3. Infected bark on large roots, buttresses or trunks should be excised back to healthy tissues, as is done for cankers and wounds. The soil should not be replaced around treated roots until late fall. After excision, exposure of infected roots to air will keep the bark dry and decrease the chances of reinfection. Healthy callus should form around the edges of all excised bark later in the season or the next spring. If callus fails to appear in an area, the condition of the bark should be checked to determine if the pathogen has advanced beyond the point of excision into healthy tissues. In this case, additional bark must be excised to remove infected tissues. This area should be examined periodically until healthy callus appears. The crown should also be thinned to compensate for loss of roots.

4. When a tree has been killed by shoestring root rot, as much of the old root system as possible should be removed before replanting. In addition, soil around the old root system should be fumigated or replaced with fresh soil. The objectives of these treatments are to reduce the amount of *A. mellea* in the soil and to remove any substrate that the fungus can live on.

BACTERIAL WETWOOD (SLIME FLUX)

HOSTS: Bacterial wetwood, a common disease affecting the xylem in many species of trees, is most prevalent in species of elm. Wetwood infection has been reported in American (*Ulmus americana*), Siberian (*U. pumila*), Chinese (*U. parvifolia*), European (*U. carpinifolia*), slippery (*U. rubra*), English (*U. procera*), and winged (*U. alata*) elms.

PATHOGEN: *Enterobacter cloacae* and other bacteria

SYMPTOMS: Wetwood can be found in the trunk, branches, and roots of elms, but is often not obvious in xylem tissue less than 10 years old. In the trunk, wetwood is characterized by dark brown discoloration, generally showing a circular pattern in cross section. When freshly cut, the discolored wood is malodorous and appears water-soaked. Most wetwood of large stems appears to be confined to a discolored central zone and to the innermost sapwood free of discoloration, but it may extend almost to the cambium in wounded stems. In trees with wilting twigs and branches, wetwood discoloration can be found in the outer sapwood and often resembles wood stained by vascular wilt fungi. In young trees (15-30 years old), the central core of of wetwood-infected tissue tapers to a point just above the stem-root interface.

Wetwood is also associated with wounds into the outer sapwood, such as those made to inject systemic fungicides. Whether wounds penetrate tissue with the wetwood bacteria present or whether the bacteria cause new wounds from the outside is not known.

Gas is produced in wetwood-infected trees from the metabolic action of bacteria. Gas composition is reported to average 46% methane, 34% nitrogen, 9% carbon dioxide, and 7% oxygen. *E. cloacae* ferments carbohydrates, producing carbon dioxide, which is converted to methane by further bacterial action. The gases, confined within the trunk, cause abnormally high pressures (4.22 kg/cm^2). Pressures fluctuate seasonally; the highest readings are observed during the summer months.

Liquid accumulates in diseased tissue. The excess liquid is thought to be either the product of bacterial metabolism in the woody substrate or the result of the difference in osmotic potentials between healthy and diseased tissues. The high gas pressures frequently force the liquid out of the stem. This "bleeding", or fluxing, is common from torn tissue in high-angled branch crotches, wounds made by pruning cuts, injection holes and trunk cracks. When contaminated with mixed populations of bacteria, yeasts, and other fungi, the exuded sap is known as slime flux. The internal gas pressures frequently open old wounds at stem crotches or in frost ribs or breaks. The liquid that bleeds from diseased wood is colorless to light yellow and turns

dark brown when exposed to the air. When bleeding is profuse, liquid flows down the bark and dries, leaving a light gray to white incrustation. If the exudation is sustained, the bark is marked by a two-colored, vertical column of brown, flanked by strips of white. The liquid frequently causes localized cambial mortality and can retard or prevent callus formation.

Wetwood can sometimes be found in root tissue as dark brown discoloration often associated with wounds and generally extending toward the main stem. Wetwood is usually not found in the grafted roots of elm.

Wilt of branches infected with wetwood is characterized by grayish brown streaks in the current-season wood, similar to those caused by vascular wilt fungi. The streaks extend from the trunk and spread into the branches. Streaks may coalesce to form solid brown rings in the wood of one or more seasons. Streaking is particularly noticeable in the springwood, and the wetwood appears water-soaked when freshly cut. Wilting may lead to dieback of branches in some cases. Scattered branches may die or the entire crown may gradually decline over a period of years. Large branches frequently show central, dark brown, wetwood-affected tissue characteristic of wetwood found in the stem. The discoloration of branch tissue is contiguous with that in the stem.

Foliar wilting is generally thought to occur when quantities of wetwood liquid are forced under pressure into the conducting xylem tissues and carried to the crown. Leaves first curl upward along their margins; then the petioles become flaccid and the leaves drop from the tree while still green or turn a dull, greenish brown, bronze color before they fall. Slowly wilting leaves may turn yellow or brown before falling. In some cases, leaves may turn yellow or dull, greenish brown between the veins. Wilting is most often seen in younger trees, while older trees are likely to exhibit a general dieback of the crown.

DISEASE CYCLE: Most bacteria associated with wetwood disease are common soil and water inhabitants. Trees with wetwood in root tissue may become infected through root wounds. Bark associated with bleeding wounds harbors large populations of bacteria that may be transported to infect other stem or branch wounds. *E. cloacae* has been isolated from the native elm bark beetle, *Hylurgopinus rufipes*, one of the vectors of Dutch elm disease. Cutting tools reportedly may transmit bacteria from diseased tissue.

CONTROL:

1. Where possible, cut out the affected area down to sound wood with a saw or hatchet and cover with a wound dressing.

2. Install drains to prevent water accumulation in branch crotches.

3. Control wood borers, carpenterworms, bark beetles and other insects which burrow into the bark or branches.

4. Avoid unnecessary injury, especially to the trunk and larger limbs. After pruning, cover exposed ends of large branches, especially those close to the trunk, with a wound dressing.

CANKER DISEASES

CAUSES: *Atropellis piniphila* - lodgepole pine and lodgepole-jack pine hybrids
Nectria cinnabarina - cotoneaster, apple, *Prunus* spp., pear, maple, elm, birch, caragana, dogwood, hazlenut, *Ribes* spp., mountain ash, saskatoon, willow and poplar
Sphaeropsis spp. - elm, maple ash, lilac and linden
Hypoxylon spp. - alder, birch, apple, poplar and linden
Diaporthe spp. - birch, dogwood, oak, willow and viburnum
Diplodia spp. - ash, poplar and elm
Septoria musiva - poplars, especially Russian and Northwest
Antibiotic stresses - frost, fire, hail, mechanical injury, etc.

SYMPTOMS: Cankers are localized lesions on the stems of plants. They may vary considerably in size. Cankers can be categorized according to their cause.

a. Infectious cankers: A typical sequence for infectious canker development is as follows: 1) the pathogen enters the host through a wound and invades and kills healthy bark, usually during a dormant period; 2) the host attempts to limit pathogen invasion by forming a layer of callus over the edge of the infected tissue; 3) the pathogen invades the callus tissue during the next dormant period; and 4) the host forms new callus. Steps 3 and 4 may be repeated each year throughout the life of the host. The form of the resulting canker will be determined by the rate of pathogen movement and the amount of callus formation.

Most infectious cankers can be placed into three groups: target cankers, diffuse cankers and canker blights. Cankers which are roughly circular and contain abundant callus throughout the canker face and at the margin are called target cankers. The pathogen spread in target cankers is relatively slow and in most cases the tree's radial increase in growth is about the same as the radial growth of the canker. Cankers which are elongated ovals and contain little callus at the margin are termed diffuse cankers. The pathogen spread in diffuse cankers is faster than in target cankers, consequently little callus is formed in advance of the canker. Diffuse cankers enlarge faster than the radial growth of the trees and often girdle trees after several years' infection. Cankers which are circular to elliptical, but contain little or no callus and increase rapidly during a single season are termed canker blights. The pathogen spread in canker blights is extremely rapid, therefore, branches and even whole trees are often girdled in a single season.

Most cankers fungi are restricted to invasion of bark tissues; however, some fungi have the unique ability to attack both the bark and the underlying xylem. Stem diseases which result from a simultaneous canker and woody decay are called canker rots.

b. Non-infectious cankers: Many non-infectious cankers are similar to infectious cankers both in appearance and developmental pattern. Non-infectious cankers often become an infection court for various pathogenic fungi, thereby creating an infectious canker.

Following are some brief descriptions of the major cankers on deciduous and evergreen trees in Alberta. Cytospora canker is discussed separately on page 48.

Hypoxylon: Small yellow to reddish-brown, slightly sunken areas appear on the bark of infected branches. As cankers enlarge the bark turns a mottled grey-black color and callus may form at the edges. Cankers enlarge from year to year and may reach 1 m or more in length before the tree is girdled. Trees may break off at the point of girdling. A brown colored sap may flow from the margin of cankers. Affected branches may produce small, yellow colored leaves. This is an important pathogen in many woodlots and shelterbelts.

Atropellis: Initially, a light resin flow may occur over a more or less circular black spot. The bark eventually ruptures and resin flow is more pronounced. Cambial tissue is killed and a blue-black discoloration occurs in the wood. Sunken cankers may eventually girdle affected trees. This can be a serious problem especially in forest stands where trees are cut for pulp and lumber.

Diplodia: This fungus causes gall and rough bark diseases. Localized woody swellings form on trunks, branches and twigs. Rough areas of proliferated bark result from late infections. The galls are small, wart-like swellings initially but later enlarge into round, black knobs encircling the stems. Black fruiting bodies of the fungus may form on infected tissue in concentric rings. Symptoms can occur on young and old growth alike. The disease is common on all species of poplar including native and hybrid stands.

Septoria: The fungus infects early season foliage in June or July. Spores produced on the leaves may infect stems, petioles, sprouts, 1-3 year old suckers or the lower parts of vigorous long shoots. Cankers on year-old shoots are small, elongate, dark brown and frequently have a pale, collapsed center in which numerous, small, pimple-like fruiting bodies of the fungus are formed. A pale, yellowish band may occasionally surround the

canker. In most cankers, marginal swellings occur in the following summer when new sapwood is formed. These result in small, spindle-shaped cankers on main branches, rarely on main stems. No 'target' cankers form because tissues within the canker dry and the fungus is soon destroyed by saprophytes. In vigorously growing trees, a new leader may readily replace cankered ones within a year. This is an important disease in nurseries because it reduces the marketable quality of rooted stock and whips for cuttings. Fully established or mature trees do not appear to be susceptible to this disease.

Nectria canker: The causal fungus produces conspicuous pink to orange-red cushions (1-3 mm diameter) on infected stems. These are spore-producing structures. The consequence of infection may include bark sloughing, wilt and branch dieback. The fungus overwinters in existing cankers.

Frost cankers: This is a common occurrence in stands which are exposed to freezing and thawing cycles during early and late winter and in Chinook areas throughout the winter. Sudden changes in temperature can kill limbs, leaders and entire trees. Aspen and poplar seem to be particularly susceptible. On these, affected branch tips turn a straw color and have a scar of healing tissue at their bases. Trees in the early years of establishment are the most prone to this type of injury. Inconspicuous blistering of the bark may occur on the trunks and branches. The injured parts of the tree may dry rapidly, blister and discolor during the dry winds, and trunk cankers or basal branch girdling may occur. As the trees grow, cankers become surrounded by poorly diferentiated sapwood under the dead bark. Complete healing may not take place. Cankers resulting from winter injury are usually spear-head shaped and many lose their bark completely. On cankered branches leafing out may be much more delayed and poor.

DISEASE CYCLE: The fungi that cause infectious cankers are usually facultative parasites. They are often found growing saprophytically on the bark of living trees and on dead branches both on the tree and on the ground. A wound is the key entry, in canker formation. The most common wound site is a branch stub, although mechanical injuries are also common sites for cankers on shade trees. Given a wound and a host in susceptible condition, canker fungi can invade healthy bark and produce a canker. Canker fungi usually produce fruiting bodies on recently killed bark. The spores from these fruiting bodies, as well as those from the same fungi growing saprophytically, serve as inoculum for new infections. Often, two types of spores are

produced: 1) forcibly discharged airborne spores capable of travelling long distances, and 2) spores that ooze from fruiting bodies and are moved locally by rain splashing.

CONTROL:

1. Canker diseases can be minimized by avoiding all unnecessary wounds and by employing sound techniques for wound treatment when pruning, cabling or any other form of essential wounding is performed on trees.

2. Control of infectious cankers can be achieved only by removal of all infected tissues. Cankers on small- to medium-sized branches can be easily removed by pruning. Cankers on the trunk or large branches that cannot be cut without destroying the value of a shade tree can be removed only by surgical excision of infected bark. Surgical excision is similar to wound treatment around trunk wounds except that additional healthy bark is sometimes removed around fast growing cankers to ensure that all infected tissues are removed.

3. Host vigor has been found to be a contributing factor in the susceptibility of trees to many canker diseases. In general, trees in poor vigor cannot heal wounds and prevent the invasion of canker fungi as well as trees that have abundant moisture and balanced soil nutrients. Therefore, regular watering and applications of balanced fertilizers are recommended to keep trees in vigorous condition.

CYTOSPORA CANKER

HOSTS: Cytospora canker occurs on a large number of deciduous trees and shrubs as well as a few species of conifers. Blue spruce, apple, crabapple, mountain ash, poplars and willows are the most common hosts in Alberta.

PATHOGEN: *Cytospora* spp.

SYMPTOMS: This disease exhibits different symptoms on deciduous than on coniferous hosts. On the deciduous trees, sunken elongate cankers form on the trunk or branches usually beginning at a branch stub or mechanical wound. The bark on the canker face is often cracked and discolored with a callus ridge at the margin. Small black pimples appear on the dead bark on the canker face. These pimples exude long thin threads of spores during wet weather. Small branches and twigs are rapidly girdled while larger branches and the main stem may take several years to become girdled. On conifers, the lowest branches are killed and then branch killing progresses up the tree. Dying branches first exhibit yellow-green then purple foliage and later cast their needles. Large amounts of resin flow from infected branches which coats the entire surface of the bark around the cankers and drips onto lower branches. Branch cankers are slightly swollen areas on the branch but can be identified most easily by their coating of resin. Cutting into the bark, however, will reveal brown areas of killed bark and cambium. Small, black pimples also occur on the cankered bark of coniferous trees, but their detection may require close inspection with a hand lens. Thin threads are also produced from these pimples during the wet weather. Trunk cankers sometimes girdle the entire tree, especially in blue spruce.

DISEASE CYCLE: Cytospora canker is caused by species of fungi in the genus *Cytospora*. *C. chrysosperma* and related cause cankers on broadleaf trees while *C. kunzei* causes cankers on spruce. These fungi overwinter as fruiting bodies on bark and as vegetative mycellium in cankers. During wet weather in the spring, fruiting bodies that appear like small black pimples on the bark exude thin threads of spores that are washed to other branches by rain splashing. These spores can also be spread by insects, pruning tools and clothing. If the spores land on a wound they can cause an infection. A canker will eventually develop as the fungus invades healthy bark. Fruiting bodies will form on the dead bark of the canker face and also on dead branches girdled by cankers. Newly formed fruiting bodies will exude spores during wet weather into late fall.

CONTROL: 1. Incidence of Cytospora canker can be minimized by keeping susceptible trees as vigorous as possible, since this disease is most severe on trees of low vigor.

2. Existing cankers can be removed by pruning. Pruning should only be done during dry weather and all cutting tools should be disinfected after each cut.

3. All unnecessary wounding should be avoided.

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DIEBACK AND YELLOWING OF LEAVES OF BIRCH

Birch trees frequently grow quite well in Alberta, under suitable growing conditions. However, to know how to grow birch trees, one should understand the conditions of their natural habitat. They are northern plants and in their natural habitat, they grow in moist shaded forest soil, and along the banks of rivers, streams, and lakes, Thus, it is evident that they thrive in a plentiful supply of water and will suffer if water is insufficient.

Roots of birch trees appear to be sensitive to high soil temperatures, such as may occur in summer following site alterations, e.g., close lawn clipping or the removal of shade offered by low growing plants. When this occurs, very often in the middle or in the latter part of the summer, the leaves on birch trees turn yellow and some leaf casting occurs. This leaf casting may be especially pronounced at the top of the tree and on some side branches. The remaining foliage may be sparse and yellow. Frequently the following year, the tops of these trees are dead and the lower branches have only sparse foliage.

It appears that the dieback of tops and yellowing of foliage of birch trees is mainly due to improper growing conditions and especially to inadequate watering. In many areas of Alberta, natural rainfall is not sufficient to supply adequate moisture for birch trees. When sprinkling lawns it is necessary to consider not only a supply of moisture for the grass but also a sufficient amount of moisture for the trees. Trees growing in lawns often receive insufficient amounts of water, because the grass absorbs most of the moisture before it gets to the tree roots. The soil under trees like birches should be soaked with water until it is saturated to a depth of at least 20 cm (8 inches) but preferably deeper (1.5 to 2 ft). Adequate water should be supplied during the hot summer months. In late summer, apply only sufficient water to maintain the grass in a green and healthy condition, so that the birch trees will mature before winter. After the trees are practically defoliated, water them thoroughly in October, in order to provide the roots with an adequate moisture supply during winter. Birch weakened by the lack of moisture are more susceptible to winter injury.

Occasionally, damage to birch trees is due to the bronze birch borer, the larvae of which mines the sap wood. Severe injury can occur and large trees may be killed in three or four years. At one time, the bronze birch borer was thought to be responsible for birch dieback. However, it now appears that the insect may be of only secondary importance, affected trees having been predisposed to attack following drought or other weakening forces. To avoid infestation of birch with borers, keep trees in the best growing conditions and in a high state of vigor.

DUTCH ELM DISEASE

HOSTS: North American species of elm such as American, slippery and winged elms are highly susceptible, while European elms such as Dutch, English and Scotch elms are moderately resistant and Asiatic elms such as Chinese and Siberian are highly resistant. At present, Dutch elm disease is not known to occur in Alberta.

PATHOGEN: *Ceratocystis ulmi*

SYMPTOMS: The earliest symptoms on the tree are yellowing and/or wilting of the leaves on a single branch usually in the upper crown. The yellowing or wilted leaves quickly turn brown and die. This symptom is known as a "flag". The symptoms rapidly spread usually one branch at a time, to progressively larger branches and eventually the entire tree. If initial symptoms begin in late spring the tree usually will be dead by the end of the summer, although large trees sometimes take several years to die. If symptoms begin in midsummer disease progression will often be limited to only a few branches. The next season, however, symptom progression often recurs in late spring and the trees are killed by late summer. If initial symptoms begin in late summer the disease will usually not progress any further during that season. Such a tree often remains free of symptoms the next season.

There exists a great deal of variability of symptom development in the Dutch elm disease. In addition to the size of the tree and the time of year that infection begins, the susceptibility of the host, the virulence of the pathogen, and the site of initial infection also strongly influence disease development. The symptom progressions previously described are for highly susceptible North American elm species that have been infected in the twigs. In species with some resistance to the disease, e.g., European elms, symptom development is much slower and sometimes the trees recover. Infection can also occur on large branches, the trunk or through the roots. In these cases, symptoms may develop as a general decline, with yellowing followed by wilting in the entire tree. These symptoms are sometimes confused with similar ones produced by elm phloem necrosis.

Symptomatic branches contain brown discoloration or "streak" in the outer xylem. This type of discoloration is a common symptom of vascular wilt diseases caused by fungi. Small twigs less than 2.5 cm in diameter should be removed from affected branches. If the outer wood is shaved with a knife a band of scattered lines of discoloration are revealed in infected twigs. Discoloration can also be found in larger branches, the trunk and sometimes the roots of severely infected trees. In dead trees or trees infected more than one season, egg galleries of bark beetles can be found beneath recently killed bark.

DISEASE CYCLE: The fungus overwinters in infected and recently killed trees, in stumps and in recently cut brush and logs, and is carried from infected wood to healthy trees by elm bark beetles. Two species of elm bark beetles (the European and the native elm bark beetle) are important vectors of this pathogen. Both of these insects lay their eggs under the bark primarily of stressed, dead or dying elms. In the late fall, the eggs hatch and produce larvae which tunnel beneath the bark. In early spring the larvae form the pupal "resting stage" and in mid to late spring emerge as adults. In infected trees, the fungus produces balls of sticky spores in the beetle gallaries. The bodies of the adult elm bark beetles are contaminated with these spores when they emerge. The European beetle feeds primarily on the bark in small twig crotches in the upper crown. The native elm beetle feeds primarily on larger branches and sometimes on the main trunk. The fungus on the insect's body is introduced into the elm tree through the feeding wounds. The fungus enters the vascular system and progressively grows through the outer xylem vessels. The fungus produces spores (cephalosporium-type) in the vessels which are thought to increase its rate of spread within the tree. As the fungus invades more vascular tissue, twigs, branches and the entire tree wilts and dies. Once a tree is dead the fungus will invade wood all through the tree, including the roots. The dying or dead tree is attractive to the female elm bark beetle looking for a place to lay eggs for the next brood. Two or three broods may occur in a single year. The overwintering brood, however, is most important for the spread of the pathogen since the trees are most susceptible when it emerges in the spring. The pathogen may also invade a healthy tree through root grafts from adjacent infected trees.

CONTROL: The incidence of Dutch elm disease in a community can be minimized by an organized program of insect vector control and prompt removal of infected hosts. A community effort is stressed because these control measures are most effective when applied to all the susceptible trees in an area. Dutch elm disease was declared a plant pest under the Agricultural Pests Act of Alberta in 1978.

1. Severely infected trees should be removed as soon as possible and the wood buried or burned before the next spring.

2. Any possible root grafts should be severed if a healthy elm tree is within 16 m of an infected one. This can be done mechanically by digging a trench 1 m deep or chemically by injection of a soil fumigant, 45 cm deep, in a line between the trees.

3. An infected tree can often be saved in the early stages of the disease by removing all infected branches. This therapeutic procedure is most effective when less than 5% of the tree is wilted. All wilted branches must be removed as well as any branches with discolored bands or streaks in the outer xylem. The pruning cuts should extend at least 30 cm beyond the last visible point of discoloration.

4. Systemic chemicals (e.g., carbendazim phosphate and thiabendazole) that can stop the growth of the pathogen, when injected into the trunk of a mildly infected tree (less than 10% wilt) can sometimes stop symptom progression of Dutch elm disease. Systemic chemicals are most effective when used in combination with pruning of infected branches. Treatments with systemic chemicals are most effective when used to prevent infection in healthy trees, but for continued protection must be reapplied each year.

5. Resistant elm species and resistant elm hybrids can be substituted for highly susceptible native elm species in areas where the former are adapted. The vase form of the American elm, however, is not found in the resistant species or hybrids.

LEAF SCORCH

SYMPTOMS: Leaf margins become lightly discolored in irregular patches and interveinal areas may appear water-soaked. Young leaves may collapse. As the condition progresses, affected tissues dry up, turn brown and become brittle. Necrotic interveinal areas may drop out producing a tattered effect. Some leaves may drop prematurely. Rapidly wilted leaves may retain a pale green color. Damage is often more pronounced on the upper, windward or southern side of the trees.

CAUSES AND PREVENTION: The main cause of leaf scorch on trees is lack of water. Many factors can affect the availability of water and its uptake by trees. Some of these are discussed below.

a) Low soil moisture in early spring.
This occurs when dry conditions occur during the fall and winter of the previous season and during the current spring. Such a situation prevails in southern Alberta in most years. Trees are in a dormant stage in winter and have low moisture requirements. In the early spring, when the trees are breaking dormancy, the demand for water increases. The amount of feeder root production and growth at this time depends, to a large extent, on the availability of moisture and nutrients in the soil.

Root growth in the spring helps the tree to take up and translocate moisture and nutrients to the developing foliage. When water is limited at this critical time, root production and growth are reduced, and less water and nutrients are taken up. As early as late May or early June, after the first few hot days, the leaves may exhibit symptoms of leaf scorch. Partial or complete defoliation may result.

When this condition develops, many tree owners apply large amounts of water. This stimulates root production and growth and the tree leaf out again and seems to be normal until the following spring when the condition recurs. Repeated defoliation weakens a tree and may predispose affected trees to winter injury and root diseases.

Prevention: Water trees as frequently as necessary during the growing season. After autumn leaf fall but before winter, fill the soil profile with water. This provides ample water for early spring root production and growth. In the spring, as the tree is breaking dormancy, water again to overcome evaporation caused by the drying winds.

b) Low soil moisture during summer
Leaf scorch symptoms are most often observed during July and August. Invariably, this condition can be traced back to inadequate soil moisture in May or June. Substantial quantities of water are evaporated from tree leaves during hot dry weather. If the water supply is deficient, the leaves may exceed their permanent wilting point and die.

Prevention: Water applied by sprinklers for the lawn often is not enough to meet tree needs. Soak the soil around the trees at regular intervals throughout the summer. Leaf scorch is less likely to occur when flood irrigation is practiced.

c) Low moisture caused by tree location
Trees growing in certain locations may have a hard time getting enough water to supply their needs, even with frequent irrigation or rains. Many trees growing in towns and cities are affected in this way. They may have a street on one side, a sidewalk on another, a driveway on another and little or no open ground within many feet of the trunk. These trees often are the first to show leaf scorch. The leaves of some trees scorch badly year after year but somehow continue to survive.

Addition or removal of soil around a tree may result in leaf scorch. Adding soil reduces aeration of the feeder roots. Water has to percolate more deeply to supply the roots with ample moisture. Removing soil from around a tree may injure the feeder roots that support the crown. Shallow-rooted trees such as birch and poplar are particularly subject to leaf scorch, especially when the soil in the root zone has been disturbed.

Trees often are planted in deep sandy or gravelly soils. Such sites have excessive water drainage and the feeder roots may be subjected to frequent drought conditions.

Shelterbelts are common in many rural areas of Alberta. The first years of growth are the most critical until the trees become fully established. Inadequate moisture and weed competition often contribute to considerable mortality in young trees.

Prevention: Supplement natural rainfall with irrigation, especially during the establishment period. Locate trees in areas where sidewalks, roads, etc. will not impair water percolation. Prune some of the branches of poorly located trees to maintain a balance between the top and roots. If done carefully, pruning

will not injure the appearance of the tree and may actually improve it.

Add soil around the base of a tree with care. An additional 3-4 cm or two likely not impair root growth, but if soil is to be added, this should be done gradually over a period of years. Provide ample aeration and additional water.

d) Excess or deficiency of nitrogen
Inexperienced tree owners often apply too much fertilizer, particularly high nitrogen fertilizer, to young or recently transplanted trees. Nitrogen stimulates top growth. Excessive top growth may require more water then can be absorbed and translocated to the leaves. Excess nutrients during the late summer may delay normal hardening. This predisposes the tree to winter injury.

A deficiency of nutrients keeps the tree in an unthrifty condition. It reduces root production and growth and subsequent top growth. Such trees also suffer more from drought and winter injury.

Prevention: Apply fertilizer according to soil test recommendations. If in doubt, underfertilization is preferable to overfertilization.

e) Insects and root diseases
Attacks by aphids, scale insects and borers rob trees of needed moisture, and can cause leaf scorch to appear earlier in the season and to be severe. Any factor (environmental, nutritional or pathological) that reduces root development and growth will weaken the tree and make it susceptible to root-invading organisms.

Prevention: Control pest insects, mites and disease wherever possible. A balanced fertility program plus adequate water and good management will maintain the tree in a vigorous condition.

Other Causes of Leaf Scorch

There are several other causes of leaf scorch in broadleaf trees. Some important ones are: saline soil, mechanical injury to the trunk and/or roots, inadvertent use of soil sterilant chemicals near trees, severe winter injury, improper use of insecticides or fungicides, and de-icing salt runoff from roadways or sidewalks.

LEAF SPOTS

CAUSES: Various species of pathogenic fungi.

SYMPTOMS: Most leaf diseases are among the least damaging disorders of shade trees. When the leaves are dropped each fall or winter, the effects of a foliar infection usually ends unless premature defoliation lowers food reserves. Leaf diseases can be grouped into the following categories to simplify their identification:

Leaf spot: - dead area on the leaf that is well defined from healthy tissue.

Leaf blotch: - dead area on the leaf that often diffuses into the healthy tissues.

Anthracnose: - Irregular dead areas on leaf margin, between and across and/or along veins, often moving onto the shoots and small twigs; sometimes whole leaves are engulfed.

Powdery mildew: - superficial growth of white to grey-white fungus material on leaves and shoots.

Leaf-blister: - leaf spot or blotch that is swollen or raised, so that the area appears blisterlike on the upper surface of the leaf.

Shot hole: - loss of dead areas inside of spots that result in a series of holes in the leaf.

DISEASE CYCLE: The fungi that attack each tree species usually are different but often have similar life cycles. Most remain dormant in the dead leaves on the ground or attached to the tree during the winter. Some pathogens survive in the buds or on dead twigs and branches. In the spring during wet weather, the pathogens become active and discharge spores that are carried by wind and splashing water, and land on the young expanding leaves. The spores quickly germinate and penetrate the leaves. By summer this infection produces symptoms similar to one of the above categories. During summer more spores are produced in these infected areas, which can cause new leaf infections during wet weather. These secondary spores are also spread by wind and water. Thus, during wet growing seasons a considerable buildup of diseases can occur, on trees.

CONTROL: Control measures for leaf diseases are usually recommended only when the health of the tree is poor or the aesthetic value of the tree would be significantly reduced due to the disease. The effect of a severe leaf infection on an already stressed shade tree could tip the balance in favor of invading microorganisms and could result in the death of the tree. In this case, control of leaf diseases is not only desirable, but could be essential to insure survival of the tree.

1. Fungicides can be used effectively to protect trees against infection from most leaf pathogens by spraying at or before bud break and every two weeks following until mid-June, with additional sprays if prolonged wet weather occurs in late spring. The key to fungicidal control of leaf diseases is application of materials before infection occurs and subsequent symptoms develop. Fungicides such as zineb, dinocap, benomyl, folpet, sulphur or Bordeaux mixture are generally recommended. Consult the manufacturer's label directions for specific information on rates and diseases controlled.

   NOTE: Spraying for leaf diseases on deciduous trees in most areas of Alberta is not usually warranted.

2. Where practical, rake up diseased leaves and bag or burn them to reduce the potential of overwintering the pathogen.

SHOOT BLIGHT OF LILAC

PATHOGENS: *Pseudomonas syringae* and *Phytophthora citricola*

SYMPTOMS: A bacterium, *Pseudomonas syringae*, can cause severe blighting of lilac shoots, leaves and flowers. The symptoms are similar to another lilac disease caused by the root-rotting fungus *Phytophthora citricola* and it may be difficult to distinguish between the two. White-flowered varieties seem to be more susceptible to *Pseudomonas* than colored types. Symptoms seen in spring are black spots on stems and leaves of young shoots which may increase in size forming large blotches. Immature leaves may turn black and die along with entire shoots which frequently curl over and wither. Inflorescences turn brown and flowers fail to develop when infected with *Pseudomonas*.

DISEASE CYCLE: *Pseudomonas* overwinters in stems and branches. Disease spread occurs most rapidly during rainy periods when bacteria are splashed from infected to healthy tissue. *Phytophtora* persists in the soil.

CONTROL: *Pseudomonas*

1. Thin out stands to promote good air circulation.
2. Prune out and destroy diseased shoots. Sterilize pruning shears between cuts by dipping them in a solution of dilute household bleach (1 part bleach: 4 parts water).
3. Avoid excessive manuring or nitrogen fertilization.
4. Some protection may be afforded by spraying with Bordeaux mixture or fixed copper at ten day intervals beginning when infection is first noticed.
5. Grow the more tolerant colored-flower varieties.

Phytophthora

1. Provide well-drained soil conditions.
2. Rogue out diseases stock.
3. Rotate plantings so lilacs are not always grown in the same spot.

SILVER LEAF

PATHOGEN: *Chondrostereum purpureum*

SYMPTOMS: The silver leaf fungus can attack poplar, willow, pear, apple, cotoneaster, hawthorn, peach, mountain ash, apricot, rose, almond, laburnum, horse-chestnut, currant and gooseberry. Orchards, cutting beds and ornamental plantings are all sites where the disease can occur. The most characteristic symptoms are a silvery or leaden sheen to the foliage and the appearance of the fruiting bodies (sporophores) of the fungus. Often only a single branch is affected. As the disease progresses, the metallic color intensifies and rusty-looking streaks may develop along the leaf midribs. Leaf splitting and browning of the margins can occur. Leaf silvering is a result of attack on the wood and a dark brown discoloration is nearly always evident, although it may be at a considerable distance below the part of the branch with silvered leaves. Affected branches may eventually die. Purple-colored fruiting bodies push their way through the dead bark. They do not form on living parts of the tree. Under moist conditions they swell and become more conspicuous.

DISEASE CYCLE: Fruiting bodies produced on dead wood release spores which may be wind borne to healthy trees. Infection usually occurs through wounds.

CONTROL:

1. Remove and burn dead wood.
2. Pick off and destroy fruiting bodies, if practical.
3. Avoid unnecessary wounding. Paint pruning wounds and other injuries with appropriate compounds, preferably those containing a fungicide.

VERTICILLIUM WILT

PATHOGEN: *Verticillium albo-atrum*

SYMPTOMS: External Symptoms - External and internal symptoms of Verticillium wilt are variable and often difficult to recognize. Usually the first external symptom is sudden wilting of foliage on one or several twigs on a branch. If the first wilting stage is not detected, and entire branch or the whole crown may show typical wilt symptoms. A general yellowing of foliage sometimes precedes wilting. Most plants first show leaf symptoms in early July; however, some trees may first show symptoms as early as March or as late as November. Leaves on affected ash species may defoliate while still green and before noticeable yellowing or wilting has occurred.

Other external symptoms that may indicate Verticillium wilt are general decline in current twig growth, dieback of individual twigs and branches, and general yellowing of the foliage. Occasionally, trees such as maple develop elongated dead areas of bark on the diseased branches or trunks where inner bark is killed. Water-soaked areas sometimes develop under the killed bark.

Plants that develop a limited amount of branch wilt during the summer may show additional wilt and dieback the following year, and others may recover and not wilt in succeeding years. Plants having extensive or general wilt throughout the crown usually die before the end of the summer.

Internal Symptoms: Sapwood discoloration often occurs in branches showing advanced stages of foliage wilt. The discoloration usually is found by making a long slanting knife cut across the end of a branch sample. In most trees, Verticillium wilt produces streaks of various shades of brown in the sapwood just under the bark. Infected maple and sumac show light to dark green streaks.

DISEASE CYCLE: The fungus is parasitic on the living tissue of many plants and can live over a year as a saprophyte in dead organic matter in the soil. The fungus spores or hyphae gain entry into the vascular system of plants through wounds made on the roots or on the branches and trunks. The spores travel in the sap stream of the outer rings of sapwood. An affected plant may start to show external symptoms at any time after the fungus becomes established and starts to grow. Proteinaceous material produced by the fungus is believed to cause the yellowing and wilting of foliage. The vascular discoloration may be caused by another material produced by the fungus that stimulates the plant cells to produce gum-like substances and structures called

tyloses which prevent sap movement in the vessels.

CONTROL:

1. Trees suspected of having Verticillium wilt should be watered immediately. Susceptible plants occasionally show symptoms of the disease while they are in a weakened condition following transplanting. Drought conditions may cause wilt symptoms on affected trees to be more severe. Affected trees should be watered every 10 to 14 days with the equivalent of 5 cm of rainfall. If the tree survives, regular watering at 2- to 3- week intervals should continue during dry periods in the summer of the succeeding year.

2. Affected trees should be fertilized to stimulate vigorous growth. For quick response, the fertilizer should be injected into the soil in liquid form or applied to the soil surface and watered in.

3. All dead branches or dead wood on branches showing wilt should be removed. Branches or twigs recently wilted should not be removed unless it is certain they are dead. Many branches that show wilt do not die, but produce a new crop of leaves 3 or 4 weeks after wilt has occurred or by the following spring. Pruning diseased branches will not eliminate the fungus that is present in the trunk or roots of the affected plant. All pruning tools should be carefully sterilized with rubbing alcohol before being used on any other plants.

4. Information on the susceptibility of most shrubs is inadequate to make definite recommendations. Narrow and broadleaf evergreen shrubs may be considered safe as replacements, since none have been found affected with the disease.

The following list represents tree genera known not to be susceptible to Verticillium wilt. These trees might be considered as replacements for trees killed by the fungus

Arborvitae	Hawthorn	Larch	Poplar
Birch	Honey locust	Mountain ash	Saskatoon
Fir	Juniper	Oak, white and bur	Spruce
Hackberry		Pine	Willow

IV. FRUIT TREES

APPLE-CEDAR RUST

PATHOGEN: *Gymnosporangium clavipes* and other *Gymnosporamgium* spp.

SYMPTOMS: Cedar or Juniper - Reddish-brown galls from 3-50 mm in diameter are formed on the branches. Older galls have circular depressions with small protuberances which enlarge to form gelatinous, yellowish-orange 'spore horns' following rainy periods in the spring. Spores are released from the horns and are carried by the wind to apple leaves. Periods of wetting and drying may cause the horns to swell and shrivel until they eventually fall off leaving a non-functional gall.

Apple - Small, pale yellow spots appear on the upper surface of leaves in the spring. These gradually enlarge and turn orange in color. Numerous spots may occur on a single leaf and young fruits may become similarly infected. By summer, small protuberances form on the underside of leaves and these later split open to release masses of brown spores. The spores may be carried by wind currents to susceptible cedars and junipers to complete the life cycle.

DISEASE CYCLE: Both types of host plant must be growning in close proximity for the disease to develop. *G. clavipes* and other species of the *Gymnosporangium* fungus may infect Saskatoon (*Amelanchier*), cotoneaster (*Cotoneaster*), quince (*Cydonia*), pear (*Pyrus*), hawthorn (*Crataegus*), mountain ash (*Sorbus*) and other rosaceous hosts.

CONTROL:

1. Prune out galls on the juniper hosts.
2. Separate the two hosts as far as possible or eliminate one.
3. Apply fungicide sprays to apples in the spring. Several applications may be necessary. Use dichlone, dinocap + mancozeb, benomyl + mancozeb, ferbam, mancozeb, metiram, thiram or zineb.

BLACK KNOT

PATHOGEN: *Dibotryon morbosum*

SYMPTOMS: Small, light brown swellings of the current or previous season's growth are the first symptoms observed. The knots may only reach a size of 1-2 cm in diameter. In the spring, knots turn olive green and have a velvety textured surface. By autumn, they turn black and harden and may be 10-15 cm long, completely encircling the limb. The knots continue to expand during successive seasons and may eventually kill the branch. Plums, cherries and chokecherries may be attacked.

DISEASE CYCLE: The fungus produces spores which are wind-blown or rain-splashed from knots to healthy branches in the spring.

CONTROL:

1. Prune away branches with knots before March 1. Cut at least 10 cm below the knots. Collect and burn all prunings with knots.
2. Eradicate infected wild *Prunus* species in the vicinity of orchards or other plantings.
3. Apply sulphur or captan at full bloom and petal fall on plums.

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Agdex 636-1
February, 1977

Alberta AGRICULTURE

Garden Fax

Replaces 275/637-2, April, 1975

FIREBLIGHT

Fireblight, a destructive bacterial disease, causes much damage to apple and crabapple trees in Alberta. It is especially noticeable in our cities and towns. Certain ornamentals such as cotoneaster and mountain ash may also be attacked. One diseased tree may provide enough bacteria to infect all susceptible trees in a city block or farm orchard. Insects are important in spreading the bacteria especially at blossoming time.

Infected blossoms become suddenly blighted and turn brown. Later, twigs and attached leaves may appear as if scorched by fire. Such leaves sometimes remain on the trees all summer and well into the winter. The bacteria tend to work their way downward into the larger branches killing patches of bark and thus forming cankers. These cankers are discolored, slightly sunken and tend to crack at their edges. If not removed they may eventually encircle affected branches causing all parts above them to die. These cankers may carry bacteria over winter. In spring drops of ooze may emerge from the edge of the "hold-over" cankers, and the bacteria in the ooze may spread by insects, rain, wind and pruning shears.

Following are ways in which the disease may be controlled. Eradication is the chief means of control where fireblight is already established. Preventive measures, however, are always important and should be widely practised.

ERADICATION

Trees with light infections may be kept alive and productive for years, provided prompt control action is taken.

(1) In late fall, winter or early spring, remove and burn all cankered limbs. Where possible, make these cuts at least 12 - 18 inches back along healthy wood. A thorough job at this time may alone be sufficient to control the disease in isolated trees.

(2) During the growing season, cut off and destroy any infected twigs several inches below the infection; but avoid excessive pruning at this time.

(3) At pruning time, work on healthy looking trees and branches first. When pruning damaged branches, disinfect shears with a solution such as lysol (1 part to 500 parts of water), household bleach (1 tablespoon/pint of water) or, mercuric chloride (1-1000).

PREVENTION

(1) Avoid susceptible varieties for new plantings (see Alberta Horticultural Guide).

(2) Remove any known sources of infection on your property by destroying badly infected trees and by pruning infected branches of others, and encourage your neighbors to do likewise.

(3) At pruning time, remove sprouts from the base of trees, and water shoots on the trunk and larger limbs. These soft growths may become easily infected if left on the trees. They provide ready access for the bacteria to trunks and larger limbs. Once the trunk is infected it may be impossible to save the tree.

(4) Avoid excessive use of high nitrogen fertilizers which promote soft susceptible growth.

(5) Blossom spraying with an antibiotic such as Agri-Strep, or with a Bordeaux mix (1:1:100) may help to prevent infection of healthy trees. The effectiveness is increased if three sprayings are applied:

(a) at early blossom stage,
(b) full bloom,
(c) late bloom.

Spraying of isolated trees may, however, be safely omitted if thorough eradication as indicated above is practised.

SHOT HOLE

PATHOGEN: *Cocomyces hiemalis*

SYMPTOMS: This fungus can attack many *Prunus* species including plum, cherry and chokecherry. The disease appears first as small, circular, purple spots on leaves. Later these spots turn brown with a definite margin and some may fall out giving leaves a 'shot-hole' appearance. Some leaves may turn yellow and fall. In the case of severe infections, complete defoliation may occur. This reduces tree vigor and branches may suffer winter injury. Fruit, stems and leaf petioles may also become infected.

DISEASE CYCLE: Fruiting bodies of the fungus overwinter on dead leaves. Spores are discharged and spread by wind currents.

CONTROL:

1. Collect and destroy infected leaves.
2. Apply fungicides, e.g., benomyl or captan, at petal fall, immediately after petal fall, at 12 day intervals (as needed) and post-harvest.

SILVER LEAF

See this disease under Section III, DECIDUOUS TREES, page 60.

V. ORNAMENTAL FLOWERS

BLACK SPOT, POWDERY MILDEW AND RUST OF ROSES

PATHOGENS: *Diplocarpon rosae* - black spot
Sphaerotheca macularis - powdery mildew
Phragmidium spp. - rust

SYMPTOMS - Black spot - Black spot is a serious and widespread fungal disease of roses. Circular black spots ranging from 2-12 mm in diameter occur on the upper sides of leaves. These spots have fringed margins unlike the distinct margins of most other leaf spots. Several spots may coalesce to form larger ones. Yellow halos frequently surround the black spots. Premature defoliation may occur when infection is severe. Cane infection produces reddish-purple lesions. Weakened bushes become susceptible to cane dieback, stem cankers and winter injury.

Powdery mildew - Powdery mildew is very common on roses. Rose types and varieties vary in susceptibility to the disease, but all popular varieties are affected. Some climbers are especially susceptible.
Leaves and young shoots become covered with a white powdery fungus growth. Younger leaves tend to curl, exposing the lower surface. When severe infections occur, the growing tip may be killed; infected buds will not open properly and leaves drop prematurely. The felty white fungus that covers diseased areas makes it easy to identify this disease.

Rust - This disease gets its name from the reddish masses of dusty spores which develop in diseased tissue. Several species of fungi can cause rose rust and some variation in symptoms can occur. Rust infection typically causes yellow to red circular spots, about 2-6 mm in diameter, beginning on the lower leaves of the plant and continuing upward. During early stages of the disease these spots may be too small to notice, and the first indication of the disease may come from a generally unhealthy appearance and loss of lower leaves. The leaves may become quite twisted and dry before falling off. The effects of this disease may be mild or severe depending on the season and how early the plants become infected.

Another form of rust affects the stems of native or old fashioned, rugosa-type roses particularly, producing massive reddish spots and swellings. This rust disease is systemic and lives from year to year in the twigs of infected plants.

DISEASE CYCLE: Black spot - The fungus overwinters on diseased leaves and canes. During the growing season, spores are spread mainly by splashing rain. Moisture on leaves favors infection.

Powdery mildew - The fungus overwinters in infected buds and leaves. Spores are the major means by which the disease spreads.

Rust - Rust fungi survive over winter on infected plant debris and canes. Spores produced during the growing season serve to spread the disease.

CONTROL: Cultural:

1. Remove all remaining foliage during the dormant season.
2. Prune out infected canes.
3. Pick off infected leaves as they are seen during the growing season if practical.
4. Plant only disease-free stock.
5. Avoid planting roses in damp, shaded locations.

Resistant Cultivars

	Black spot	Mildew	Rust
Hybrid Tea			
Bewitched	Resistant	Resistant	Susceptible
Ena Harkness	Resistant	Susceptible	Susceptible
Miss All American Beauty	Resistant	Resistant	Susceptible
Peace	Resistant	Intermediate	Susceptible
Red Devil	Intermediate	Resistant	Resistant
Tiffany	Resistant	Intermediate	Intermediate
Grandiflora			
Comanche	Resistant	Intermediate	Susceptible
Queen Elizabeth	Resistant	Susceptible	Intermediate
Scarlet Knight	Intermediate	Intermediate	Intermediate
Floribunda			
Most cultivars are resistant to the three diseases.			
Shrub Roses			
Adelaide Hoodless	Susceptible	Resistant	---
Cuthbert Grant	Resistant	Resistant	Intermediate
Prairie Princess	Intermediate	---	Resistant

Chemical Applications: Lime sulphur 1:9 as a dormant spray followed by sulfur, folpet, captan, zineb, ferbam or benomyl during the growing season.

NOTE: Benomyl, folpet and captan will not control rust; captan, ferbam and zineb will not control mildew. There are a number of fungicide-insecticide mixtures registered for use on roses.

BULB, CORM AND TUBER ROTS

PATHOGENS: *Botryotinia draytonii* - gladiolus
Stromotinia gladioli - gladiolus
Fusarium oxysporum - galdiolus, narcissus, tulip
Penicillium spp. - gladiolus, iris, tulip, begonia
Sclerotinia tuliparum - tulip

SYMPTOMS: Fleshy organs show varying degrees of discoloration and decay. Fungal sporulation frequently occurs on affected areas when humidity is high. Plants growing from slightly or moderately affected corms may exhibit stunting, chlorosis and/or premature death. Severely affected organs generally decay in the ground and shoots never emerge.

DISEASE CYCLE: The causal fungi generally survive on affected organs and in the soil where bulb crops were previously grown.

CONTROL:

1. Sort bulbs, corms and tubers carefully after harvest and before planting and destroy any with obvious symptoms of infection.
2. Avoid planting bulb plants in infested fields.
3. Follow a 3-5 year rotation avoiding other bulb plants.
4. Plant in beds with good air and soil drainage.
5. Rogue diseased plants when they are seen.
6. Captan, benomyl or thiabendazole applied as a dip may be effective in controlling bulb rots. Consult the manufacturers' label directions for information on crops, rates and treatment procedures.

DAMPING-OFF

PATHOGEN: Various species of *Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Phoma* and *Sclerotinia*.

SYMPTOMS: Preemergence damping-off - Seed rots in soil or seedling dies before it comes up.

Postemergence damping-off - seedlings affected after emerging from soil but while still small and succulent. Stem tissues at soil line become water soaked and browned or blackened depending largely on the fungus involved. Shrivelling of affected tissue may follow and seedlings topple over.

CONTROL:

1. Sterilize soil with formalin, steam, methyl bromide, metam-sodium, methyl isothiocyanate or dazomet.
2. Treat seed with a fungicide dressing (captan or thiram) prior to planting.
3. Provide good ventiliation to keep humidity low.
4. Water in the morning to allow the foliage to dry by evening.
5. Avoid overfertilization, especially with nitrogen.
6. Do not sow seeds too thickly.
7. If damping-off appears, water flats or seedbeds with solutions of captan, thiram or oxine benzoate.

BOTRYTIS (GRAY MOLD)

PATHOGEN: *Botrytis cinerea*

SYMPTOMS: Grey mold is a common disease of plants, especially herbaceous ornamentals, grown under humid conditions. Greenhouse, small fruit and field crops may also be attacked. Seedling damping-off, blossom blight, fruit rot, stem and crown rot and shoot blight may all be caused by *Botrytis*. Initially, a water soaking and collapsing of the tissue occurs. Under humid conditions abundant grey fungal growth develops on infected plant parts. Millions of spores are produced and may be easily blown or splashed onto healthy plants. Small, dark, hard sclerotia may eventually form in the decayed tissues. Spores germinate and reinfect only if a film of moisture is present on the plant surface.

DISEASE CYCLE: *Botrytis* spreads rapidly when spores are dispersed by wind currents. Sclerotia are durable resting structures which permit the fungus to overwinter and survive other unfavorable conditions.

CONTROL:

1. Collect and destroy infected debris.
2. Maintain free air circulation around plants to reduce high humidity.
3. Apply protective fungicidal sprays using materials such such as benomyl or sulphur + zineb.

POWDERY MILDEW

PATHOGENS: *Erysiphe* spp., *Sphaerotheca* spp., *Microsphaera* spp., *Phyllactinia* spp. and *Uncinula* spp.

SYMPTOMS: A wide variety of flowers, shrubs, trees and turf grasses are susceptible to powdery mildew fungi. The disease may be recognized by a white to grey or slightly brownish powdery growth over the surface of leaves, stems, buds, fruits and flowers. Infected leaves may be distorted, curled or twisted and smaller than normal with a yellowish color.

DISEASE CYCLE: The fungi overwinter in leaf debris, stems and dormant buds. Spores dispersed by wind and rain spread the disease.

CONTROL:

1. Grow mildew tolerant or resistant plant varieties whenever possible.
2. Avoid planting in shady locations where air circulation is poor.
3. Do not fertilize excessively with nitrogen.
4. Clean up dead, infected plant material in the fall.
5. Avoid overcrowding plants.
6. Apply fungicides such as benomyl, dinocap + captan, captan + thiophanate-methyl, captan + sulphur, tribasic copper sulphate, dinocap + zineb, sulphur + zineb, folpet, folpet + sulphur or lime sulphur.

VI. TURFGRASS

Alberta AGRICULTURE

Garden Fax

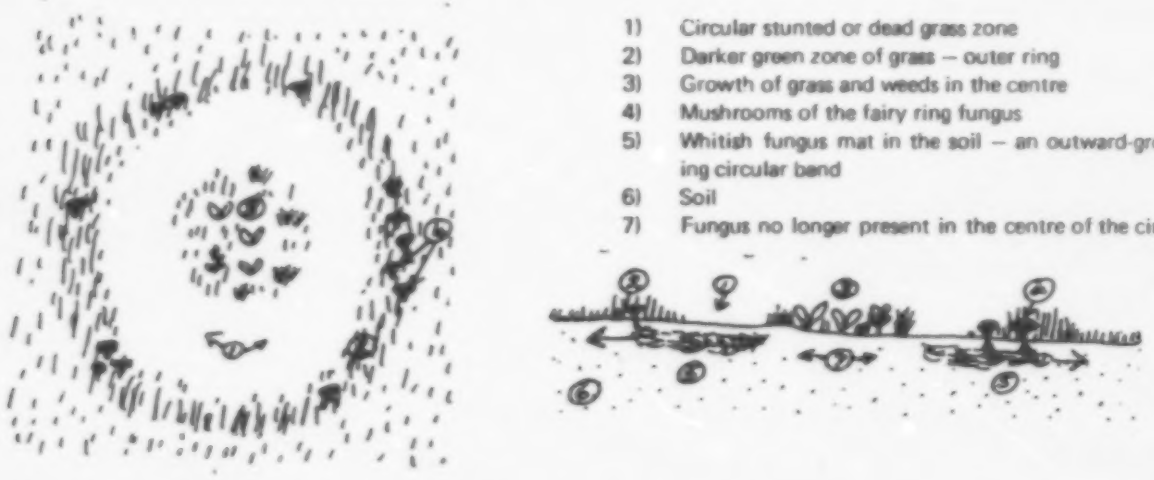
Agdex 606-6

March, 1977

FAIRY RING IN TURF GRASSES

Rings and crescents of dark green, unthrifty or dead grass in lawns, fairways and other grassed areas can be caused by the fairy ring fungus *(Marasmius oreades)*. Rings or crescents commonly vary from 1 to 10 ft in diameter and are generally problems on turf that has been established for 5 or more years. Spores (seeds) of the fungus germinate and start their growth on a particular spot in the grassed area. The fungus grows by means of a white thread-like network visible as a white mouldy-appearing band just below the soil surface. This white band will vary from 1 inch to over 1 ft in depth in the soil and covers a circular area.

The fairy rings expand in diameter at the rate of inches to feet per year. A fairy ring of around a quarter mile in diameter has been observed in a short grass prairie area of southern Alberta. The fungus does not attack the grass directly in the manner of a parasitic disease, but lives on organic matter in the soil, creating a zone or band in the soil preventing water penetration and percolation. This leads to dehydration and death of the turf grasses that grow immediately above the fungus mat. As the fungus moves through the soil generally in a circular or semi-circular pattern and expands in area, the older part of the fungus mat dies off and grass or weeds can now regrow in this older or centre area.



1) Circular stunted or dead grass zone
2) Darker green zone of grass -- outer ring
3) Growth of grass and weeds in the centre
4) Mushrooms of the fairy ring fungus
5) Whitish fungus mat in the soil -- an outward-growing circular band
6) Soil
7) Fungus no longer present in the centre of the circle

Fairy ring from above and in soil profile.

The fungus mat never grows back into the ring, always outwards, apparently since it has used up the suitable organic food source that existed there previously. On the outer edge of the ring the grass often appears taller and more vigorous; it appears to be stimulated in some way by the fungus growth, though, as the season passes, this grass will become stunted or killed by the advancing fungus mat. Tan-coloured mushrooms (toadstools) grow along the outer edge of the fairy rings in the fall, or during a wet summer. These are the fruiting structures of the fungus. The mushrooms produce the spores or seeds responsible for propagation of the fungus.

CONTROL OF FAIRY RINGS

Fairy rings are difficult to control. There are no known effective and simple chemical control procedures. Since the probable cause of damage is primarily associated with dehydration, suppression of fairy rings might be more practical than eradication.

SUPPRESSION

1. Pierce the soil repeatedly with a fork closely in and around the edges of the rings to a depth of 6 inches or more. This is intended to allow water penetration through the fungus mat.

or

2. Punch holes 1/4 to 1 inch in diamter 3 inches apart, to over 1 ft deep along the ring.

or

3. Use a tree feeding lance or root feeder attachment on a regular garden hose to force water into the ring to a depth of 10 to 20 inches.
4. Water the affectec areas frequently, every two days during dry weather, and continue this schedule for a month or more during the warmer months. Maintain a regular fertilizer schedule with an adequate supply of nitrogen.

These procedures, while not eliminating the fairy ring fungus, will prevent the appearance of dead petches of grass. It will result in some uneven green areas of grass.

ERADICATION

If only a few rings are present, then it might be practical to attempt the following procedures, though success is not guaranteed.

1. Remove the turf in a zone of around 18 inches to the outside and inside of the affected area. Do not spill any of the turf or soil on the rest of the lawn.
2. Remove the soil in this area to at least a few inches below the zone of the white fungus mat.
3. Replace the excavation with fresh top-soil and returf or reseed.

LEAF SPOT AND MELTING OUT

PATHOGEN: *Helminthosporium* spp.

SYMPTOMS: The disease symptoms can range from leaf spotting to root, rhizome and crown rots. In a moderate infection, only a slight leaf browning may occur, but in severe cases patches of grass may die. The latter symptom usually occurs when plant vigor is suppressed for reasons such as drought or poor soil fertility. Bluegrasses are particularly susceptible.

DISEASE CYCLE: Spores are produced by the fungus during periods of warm moist weather. They may be disseminated by lawn mowing, wind, etc. Overwintering occurs in infected debris.

CONTROL:

1. Maintain turfgrass in good health by adequate fertilization and watering. Avoid excessive nitrogen applications. Apply enough water each time to soak the soil at least 15-20 cm deep. Avoid frequent light sprinklings and waterlogging of the soil.

2. Mow grasses at the recommended maximum height for satisfactory turf use. Avoid cutting too close to the ground.

3. Grow Kentucky bluegrass varieties with resistance to the disease, e.g., Merion, Bristol, Nugget and Touchdown. Baron, Fylking, Newport, Windsor and Sydsport have intermediate resistance to melting out.

4. Apply sprays of captan, anilazine, iprodione, maneb, quintozene or chlorothalonil at 10-14 day intervals when conditions favor disease development and spread.

POWDERY MILDEW

PATHOGEN: *Erysiphe graminis*

SYMPTOMS: Powdery mildew is first noticeable as small greyish-white spots on the leaves. These spots eventually enlarge to cover the whole leaf. Infected leaves eventually yellow, wither and die. Minute black dots (sexual fruiting bodies of the causal fungus) eventually form on the infected leaves. The disease is most prevalent in shady areas.

DISEASE CYCLE: Powdery mildew overwinters on infected plant debris. In the spring, spores are produced which can be carried by wind or splashing rain to living grass blades where infection subsequently occurs. Crops of spores produced during the growing season serve to further spread the disease.

CONTROL:

1. Avoid close mowing.
2. Avoid excessive nitrogen.
3. Use creeping red fescue in shaded locations.
4. Dormie, Sydsport, Nugget and Delft are resistant to powdery mildew. Arista, Delta, Fylking and Merion have intermediate resistance, while Park and all *Poa annua* strains are susceptible.
5. If infection is severe, apply thiophanate-methyl at 14-day intervals.

SNOW MOLD

PATHOGENS: *Myriosclerotinia borealis* - bentgrass
Fusarium nivale - bentgrass
Coprinus sp. - bentgrass
Typhula incarnata and *T. ishikariensis* - bluegrass

SYMPTOMS: Snow molds damage lawns during the period when snow covers the grass, especially in shaded or wet areas where the snow is slow to melt. Compaction of snow seems to favor the disease. Symptoms of snow mold become evident in the early spring with the appearance of irregular patches of dead turf. A mass of cottony fungal growth is often seen in these areas after the snow melts. The color of the fungal growth may vary from white to grey or pink depending on the species of fungus involved.

DISEASE CYCLE: The pathogen oversummers as spores, sclerotia or mycelial growth in dead grass blades, crowns and rhizomes. They may be spread by mowing, foot traffic, etc.

CONTROL:

1. Let turf "harden off" before winter.
2. Mow in late fall and remove all leaves and debris.
3. Use a balanced fertilizer in adequate amounts.
4. Improve air and soil water drainage.
5. Reduce snow cover with fences, by spreading drifts, and/or by removing trees and bushes.
6. Renovate and re-seed severely diseases areas.
7. Plant resistant cultivars:
   a. Bentgrass - Penncross, Astoria and Exeter for *F. nivale*
      - Seaside for *M. borealis*
   b. Bluegrass - Dormie and Park for *Coprinus* sp.
      - Adorno, Monopoly and Park for *Typhula* spp.
8. Apply protective fungicide sprays in fall before permanent snow cover arrives using:
   a. Bentgrass - benomyl, quintozene, oxycarboxin + thiram + carboxin, chlorothalonil or thiophanate methyl for *F. nivale*.
      - quintozene for *M. borealis*.
   b. Bluegrass - oxycarboxin + thiram + carboxin, mercuric + mercurous chloride, or quintozene for *Coprinus* sp.

- chloroneb, iprodione, oxycarboxin + thiram + carboxin, quintozene or chlorothalonil for *Typhula* spp.

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Canada Canada
metric métrique

METRIC CONVERSION TABLE

Approximate conversions to metric measures

When You Know	Multiply by	To Find	Symbol
LENGTH			
inches	2.5	centimetres	cm
feet	0.3	metres	m
yards	0.9	metres	m
miles	1.6	kilometres	km
AREA			
square inches	6.5	square centimetres	cm^2
square feet	0.09	square metres	m^2
square yards	0.8	square metres	m^2
square miles	2.6	square kilometres	km^2
acres	0.4	hectares	ha
MASS			
ounces	28	grams	g
pounds	0.45	kilograms	kg
short tons (2000 lb)	0.9	tonnes	t
VOLUME			
fluid ounces	28	millilitres	ml
pints	0.57	litres	l
quarts	1.14	litres	l
gallons	4.5	litres	l
cubic feet	0.03	cubic metres	m^3
cubic yards	0.76	cubic metres	m^3
TEMPERATURE (exact)			
Fahrenheit		Celsius	°C

°F − 32 x 5/9 = °C

TABLE DE CONVERSION MÉTRIQUE

Conversion approximative aux unités métriques de mesure

Lorsque vous connaissez les mesures en	Multipliez par	Pour obtenir	Symbole
LONGUEUR			
pouces	2.5	centimètres	cm
pieds	0.3	mètres	m
verges	0.9	mètres	m
milles	1.6	kilomètres	km
SUPERFICIE			
pouces carrés	6.5	centimètres carrés	cm^2
pieds carrés	0.09	mètres carrés	m^2
verges carrées	0.8	mètres carrés	m^2
milles carrés	2.6	kilomètres carrés	km^2
acres	0.4	hectares	ha
MASSE			
onces	28	grammes	g
livres	0.45	kilogrammes	kg
tonnes courtes (2000 lb)	0.9	tonnes	t
VOLUME			
onces liquides	28	millilitres	ml
chopines	0.57	litres	l
pintes	1.14	litres	l
gallons	4.5	litres	l
pieds cubes	0.03	mètres cubes	m^3
verges cubes	0.76	mètres cubes	m^3
TEMPÉRATURE (exacte)			
Fahrenheit		Celsius	°C

°F − 32 x 5/9 = °C

Metric Commission

Commission du système métrique

Simple Conversion Table of Length

Inches	1	2	3	4	5	6	7	8	9	10	11	12
Centimetres	2.54	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	27.94	30.48 (approx 0.3 m)
Feet	1	2	3	4	5	6	7	8	9	10		
Metres	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0		
Miles	1	2	3	4	5	6	7	8	9	10		
Kilometres	1.6	3.2	4.8	6.4	8.0	9.7	11.3	12.9	14.5	16.1		

Simple Conversion Table of Weight

Ounces (av)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grams	28.3	56.7	85.0	113.4	141.7	170.1	198.4	226.8	255.1	283.5	311.8	340.2	368.5	396.9	425.2	453.6*
Pounds	1	2	3	4	5	6	7	8	9	10						
Kilograms	0.45	0.91	1.36	1.81	2.27	2.72	3.18	3.63	4.08	4.54						

*(approx 0.45 kg)

Simple Conversion Table of Temperature

Degrees Fahrenheit	0	10	20	30	32*	40	50	60	70	80	90	100	200	212	400
Degrees Celsius	-17.8	-12.2	-6.7	-1.1	0*	4.4	10.0	15.6	21.1†	26.7	32.2	37.8	93.3	100.0	204.4‡

*(Water Freezes)
†(Room Temperature)
‡(Hot Oven)

Simple Conversion Table of Area

Square Inches	1	2	3	4	5	6	7	8	9	10
Square Centimetres	6.45	12.90	19.36	25.81	32.26	38.71	45.16	51.61	58.06	64.52
Square Feet	1	2	3	4	5	6	7	8	9	10
Square Metres	0.09	0.19	0.28	0.37	0.46	0.56	0.65	0.74	0.84	0.93
Acres	1	2	3	4	5	6	7	8	9	10
Square Metres	4 047	8 094	12 141	16 187	20 234	24 281	28 328	32 375	36 422	40 469

Simple Conversion Table of Volume

Ounces (fl.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Millilitres	28.4	56.8	85.2	113.7	142.1	170.5	198.9	227.3	255.7	284.1	312.5	341.0	369.4	397.8	426.2	454.6
Ounces (fl.)	17	18	19	20												
Millilitres	483.0	511.4	539.8	568.3 (approx. 0.57 ℓ)												
Pints	1	2	3	4	5	6	7	8	9	10						
Litres	0.57	1.14	1.70	2.27	2.84	3.41	3.98	4.55	5.11	5.68						
Gallons	1	2	3	4	5	6	7	8	9	10						
Litres	4.5	9.1	13.6	18.2	22.7	27.3	31.8	36.4	40.9	45.5						

POOR

QUALITY

ORIGINAL